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PASSIVE OPTICAL SAMPLE ASSEMBLY (POSA): FINAL REPORT

By Roger C. Linton, Edgar R. Miller, and Michael Susko
Space Sciences Laboratory

August 1981

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George C. Marshall Space Flight Center
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16. ABSTRACT

The Passive Optical Sample Assembly (POSA) is a passively deployed array of contamination-sensitive samples. A POSA unit was mounted and flown in the cargo bay of the Space Shuttle Columbia during the first Orbital Flight Test (OFT-1). A similar unit was mounted in a different location in the cargo bay at Dryden Flight Research Center during the postflight operations there prior to the ferry flight return of Columbia to Kennedy Space Center.

The samples in both POSA arrays were subjected to a series of optical and analytical measurements prior to delivery for installation in the cargo bay and after retrieval of the flight hardware. This report presents the final results of a comparison of the two series of measurements. These STS-1 results are based on data obtained from only a portion of one of the ten Induced Environment Contamination Monitor (IECM) instruments to be flown on several Shuttle flights beginning with STS-2. These limited results do not indicate Shuttle contamination levels in excess of those anticipated. Much more definitive data will be obtainable from planned flights of the full IECM.

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Passive optical experiment
OFT-1 experiment

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INTRODUCTION

An array of contamination-sensitive collector surfaces was mounted and flown in the cargo bay of the Space Shuttle Columbia (STS-1) during the first Orbital Flight Test (OFT-1), April 12-14, 1981. A similar array was mounted in a different location in the cargo bay at Dryden Flight Research Center during the postflight operations there prior to the "ferry flight" of Columbia back to Kennedy Space Center (KSC). Designated as the Passive Optical Sample Assembly (POSA), the arrays were flown to aid in the assessment of contamination hazards of the Shuttle cargo bay for future missions.

POSA is a modified version of one of the instruments included in the Induced Environment Contamination Monitor (IECM), an integrated technology payload consisting of 10 individual instruments sharing a common power and data collection system. The IECM, designated for flight on all Orbiter Flight Tests (OFT's) succeeding the first and on Spacelabs 1 and 2, is designed to provide verification measurements of Shuttle contaminant emission and deposit levels during ground operations, ascent, on-orbit, descent, and postlanding. The POSA, modeled after its parent IECM experiment (Passive Sample Array), was included on OFT-1 to provide baseline contamination verification of the Shuttle environment for the design and user communities.

The POSA unit flown on the orbital phase of the mission was mounted on the Development Flight Instrumentation (DFI) pallet. It will henceforth be designated as the POSA/DFI unit. The POSA unit mounted for just the ferry flight will be designated as the POSA/FF. Samples in the POSA/DFI were subject to deposition of contaminants throughout prelaunch, ascent, orbital, descent, and ferry flight phases of the OFT-1 mission. Inclusion of the second POSA unit, POSA/FF, during the ferry flight phase of the mission provided a means of identifying contamination hazards peculiar to that single phase of the mission.

Both POSA units are totally passive in nature. Each is a mounted array of five optical samples and three static-charged Teflon sheets (electrets). Circumstances led to the inclusion of only two electrets on the POSA/FF unit. Also, uv-grade fused silica was substitued for the CaF_2 window (sample D) for POSA/FF.

Tables 1 and 2 provide directories of the samples contained in the POSA units. The basic composition and criteria for selection of the samples flown are included in Appendix A. All of the samples were subjected to a series of optical and analytical measurements at the Marshall Space Flight Center (MSFC) prior to delivery for installation at KSC and Dryden Flight Research Center. The measurements were repeated in an identical manner at MSFC following retrieval of the flight hardware.

TABLE 1. PASSIVE OPTICAL SAMPLE ASSEMBLY (POSA),

DFI PALLET UNIT

Tray 012	
Sample	Material
A	Magnesium Fluoride Overcoated Aluminum (MgF_2/Al)
B	Gold Mirror
C	1810 Å Filter
D	CaF_2 Window (calcium fluoride)
E	Top: CaF_2 Window
	Base: Electret No. 9
F	Top: Electret No. 11
	Base: Electret No. 10

TABLE 2. PASSIVE OPTICAL SAMPLE ASSEMBLY (POSA),

FERRY FLIGHT UNIT

Tray 05	
Sample	Material
A	MgF_2/Al Mirror
B	Gold Mirror
C	1790 Å Filter
D	UV-Grade Fused Silica
E	CaF_2 Window
F	Top: Electret No. 14
	Base: Electret No. 13

DESCRIPTION OF HARDWARE

Each POSA unit consists basically of a rectangular holder with six cylindrical receptacles (1.09 in. wide by 0.187 in. deep) bored at equal spacing. Smaller (0.75 in. diameter) holes in each of the sample "slots" are counterbored completely through the holder so that effluents can reach front and rear surfaces of the samples.

A retainer plate with six circular "apertures" is bolted over the sample holder, allowing maximum front-surface exposure of the samples while holding down the outer edges. During those phases of ground handling, transportation, and installation when exposure was not desired, a solid, rectangular cover plate with captive screws was attached to protect the samples. The POSA hardware was machined from 300 series stainless steel. A more detailed description of the POSA hardware, including assembly and handling specifications, is available in a prior publication [1].

POSA MISSION DETAILS

The POSA/DFI unit was mounted to the starboard rail of the DFI pallet (X_o = 1069) in the Shuttle cargo bay. In Shuttle coordinates, the array was mounted in the X, Y plane, with the samples' surface normal parallel to the Shuttle Z-axis (Fig. 1).

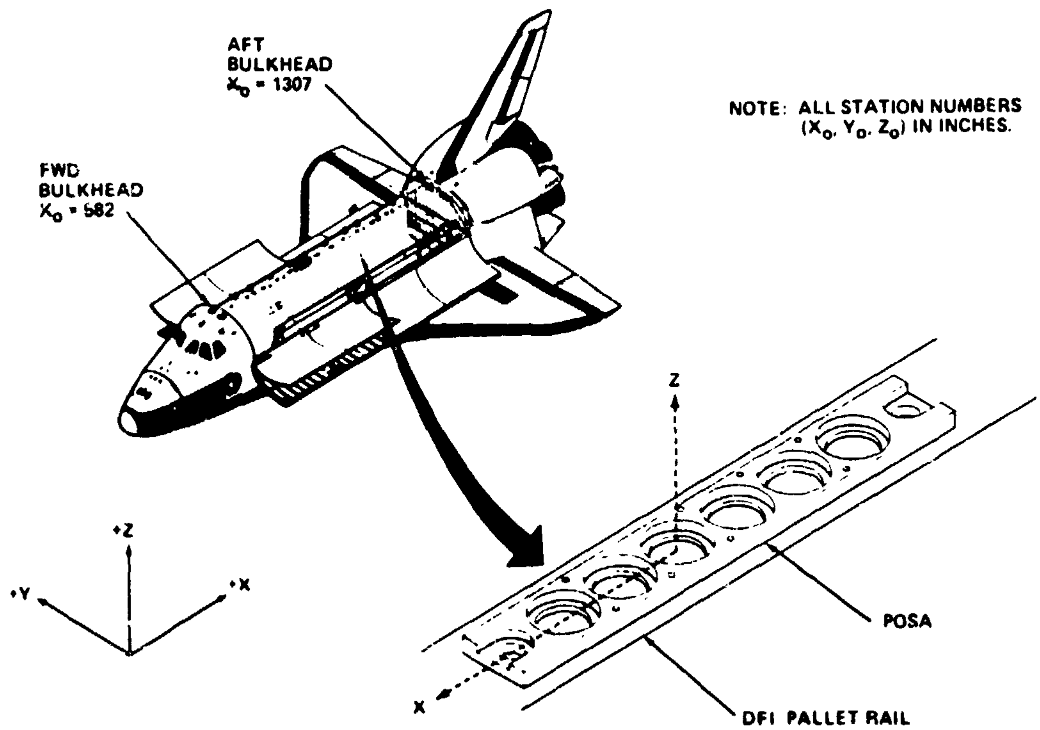

Figure 1. Shuttle Orbiter configuration.

The POSA/FF unit was separately mounted, postlanding at Edwards AFB, at a cargo bay location specified by X_o = 750, inside access door No. 44.

A summary of pertinent mission timeline details was provided in the "quick-look" report [2]. It is necessary to consider that the samples of the POSA/DFI unit were exposed, uncovered, in the cargo bay for nearly a month prior to launch. During this period, the cargo bay doors were closed with no access of personnel. With reference to both units, there were 9 days of exposure to the ambient cargo bay environment on the ground at Edwards AFB.

PHOTOGRAPHIC EVALUATION

The flight units were returned to MSFC on May 7, 1981. They were photographed, as received on May 8 (Figs. 2 through 9) in the environment of a class 10,000 laminar flow bench. The larger particulates (and/or fibers) can be readily observed in the photographs on the samples of both units; considerably greater amounts of particulates of smaller size can be seen on closer inspection under magnification (see Particulate Analysis, later in this report). Visual inspection of the samples from both POSA units reveals no direct evidence of a contaminant film, with the single exception of the magnesium fluoride overcoated aluminum (MgF_2/Al) mirror of the POSA/DFI unit (Figs. 2 and 3). The smudge and the droplet on this sample were examined with the magnification of a phase-contrast microscope (Figs. 10 through 12). From examination of these photographs, the "dendritic" pattern in the smudge lacks the regularity and pattern of true crystalline dendritic growth. Since the smudge and the droplet were later determined to have the same conposition (see Chemical Analysis, later in this report), and the droplet has no such pattern, the conclusion of human involvement with, perhaps, a fine-haired brush is more likely as a source for the smudge pattern.

RESULTS – OPTICAL MEASUREMENTS

Optical measurements of the POSA samples were performed on two separate instrumentation facilities. In the wavelength range 120 to 290 nm, specular spectral reflectance and transmittance (at near-normal incidence) were measured in a reflectometer at the exit slit of a Seya-Namioka-type monochromator. A hydrogen discharge lamp was utilized as the source. The measurements were extended through 2.5 μm wavelength (overlapping slightly in the near uv) by measuring the diffuse reflectance and backscatter coefficient in a Beckman/Gier-Dunkle integrating sphere facility, on two of the samples in each POSA unit.

The results of the diffuse reflectance measurements are shown in Figures 13 and 14. Neither of the POSA/FF samples measured in the Gier-Dunkle facility (0.25 to 2.5 μm) indicates any degradation through that spectral range. The gold mirror of POSA/DFI indicated some degradation (~ 2 percent) in the near-ultraviolet.

The smudged MgF_2/Al mirror from the POSA/DFI unit indicated, by these diffuse reflectance measurements, a 10 percent relative increase in mirror absorptance. Backscatter measurements on this sample, in this range, indicated an increase more than double the original level, although the levels (0.02 preflight, 0.07 postflight) are, in magnitude, subject to large uncertainty.

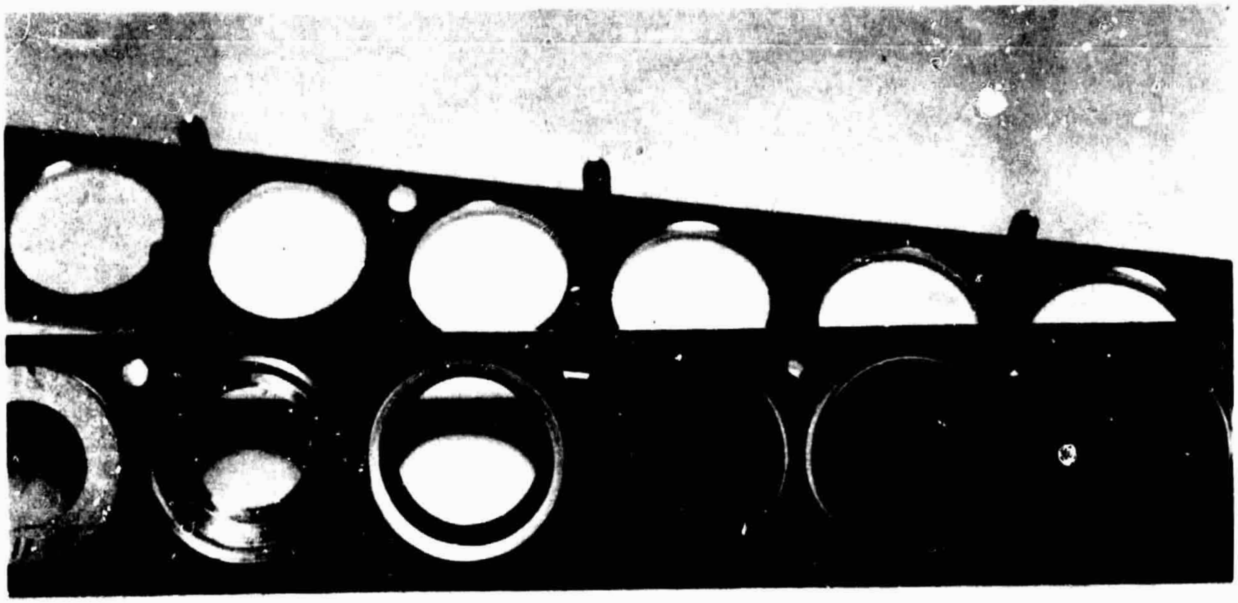

Figure 2. POSA/DFI postflight.

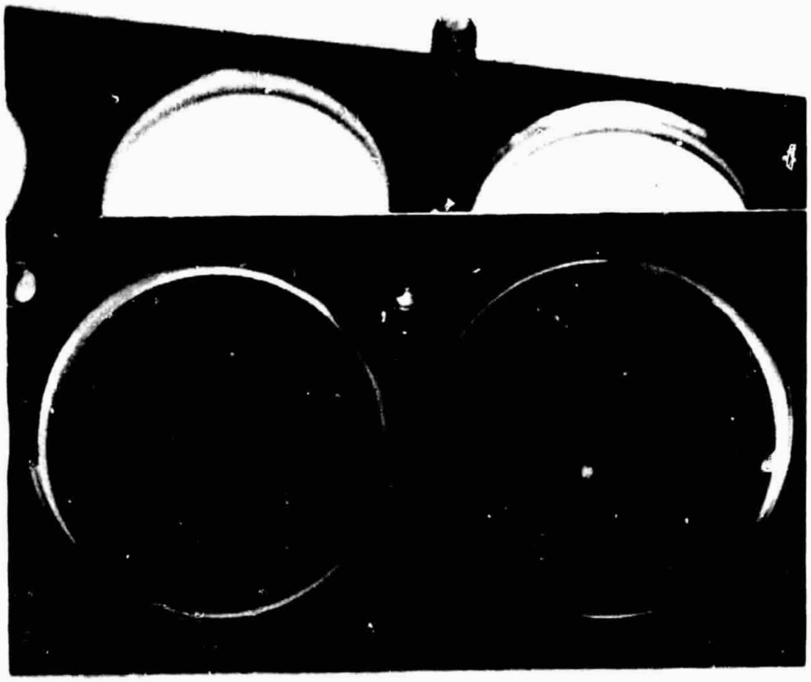

Figure 3. POSA/DFI: sample positions A and B (MgF_2/Al, gold).

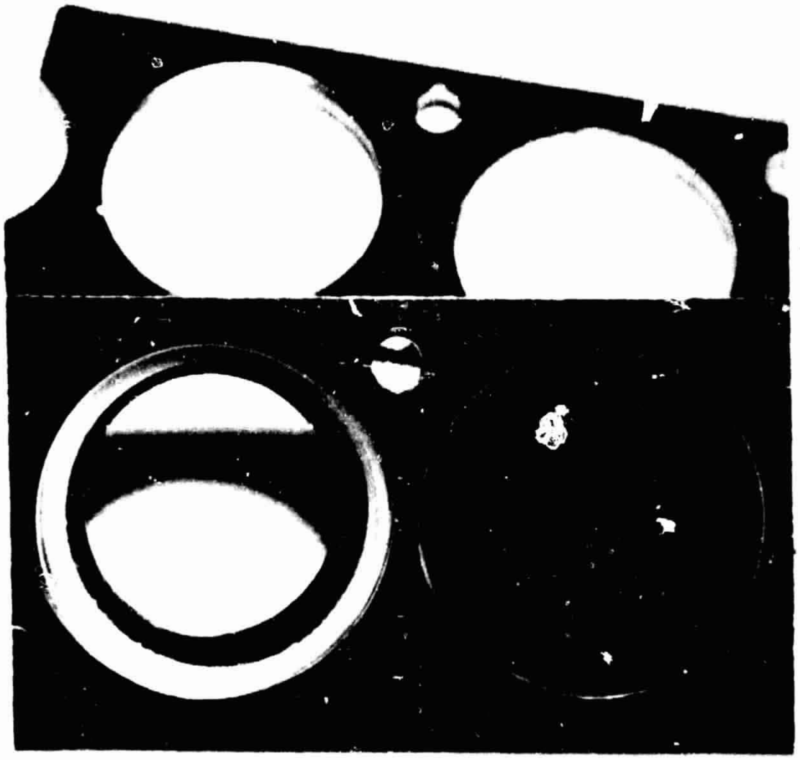

Figure 4. POSA/DFI: sample positions C, D (1810 Å filter, CaF_2).

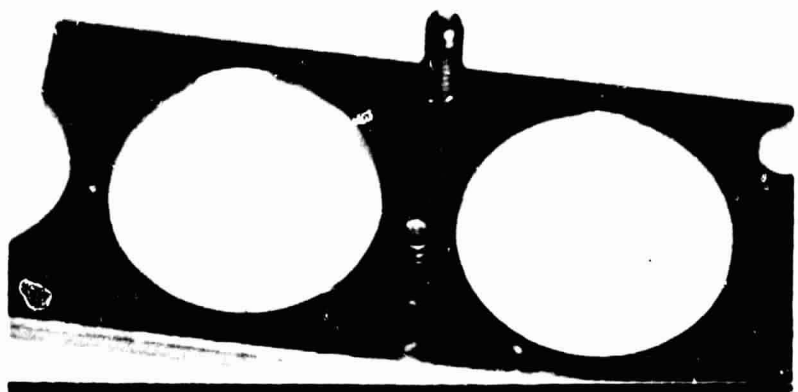

Figure 5. POSA/DFI: sample positions E, F (CaF_2 No. 2, electrets).

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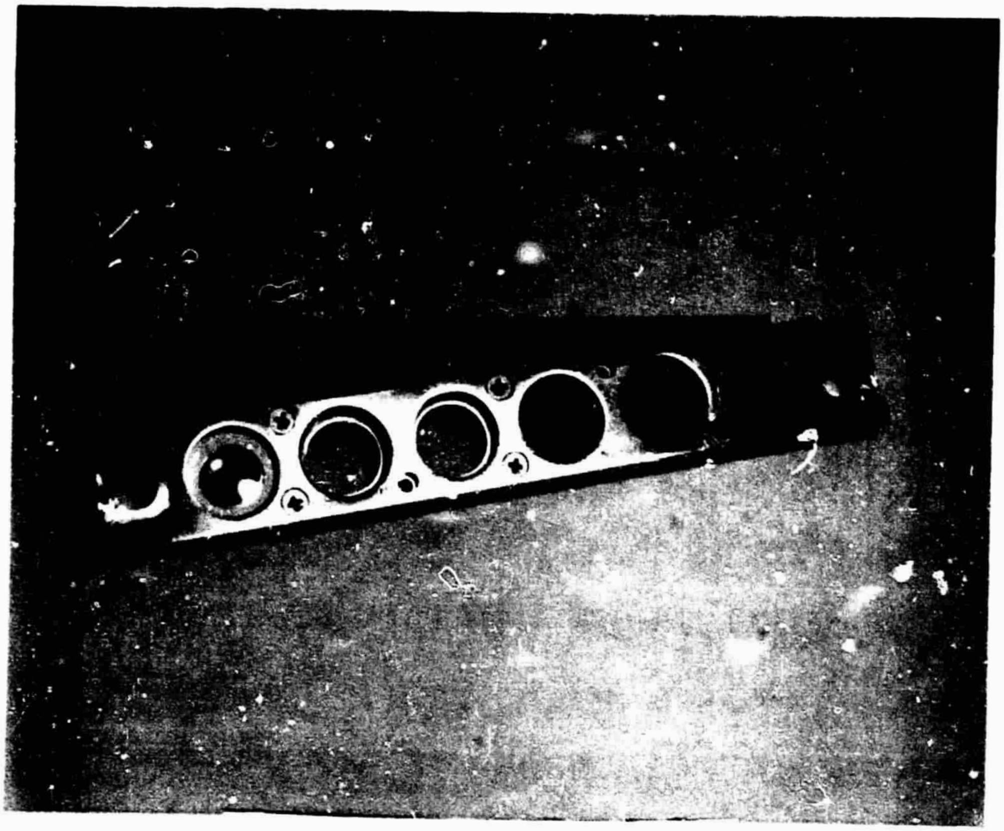


Figure 6. POSA/FF.

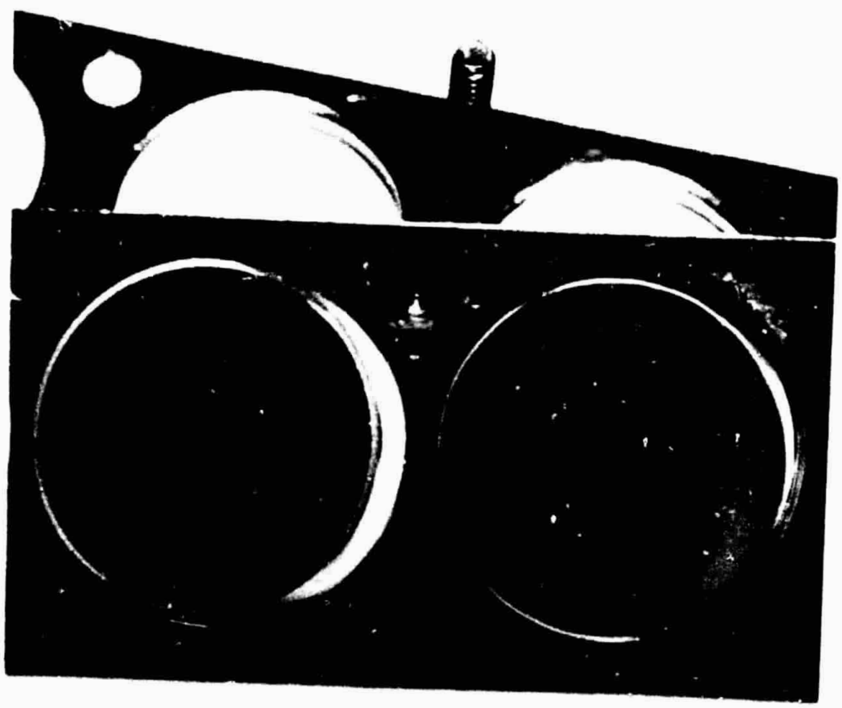


Figure 7. POSA/FF: sample positions A, B (MgF_2/Al, gold).

Figure 8. POSA/FF: sample positions C, D (1790 Å filter, fused silica).

Figure 9. POSA/FF: sample positions E, F (CaF_2, electrets).

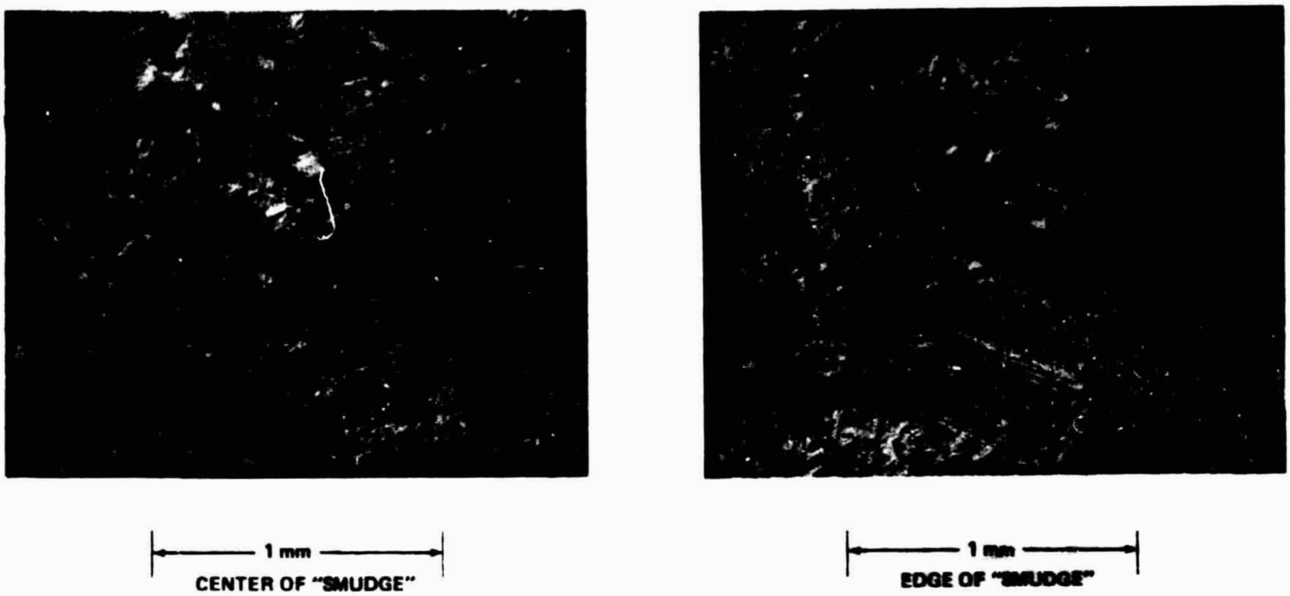


Figure 10. Phase-contrast microphotographs of "smudge" on sample A (MgF_2/Al) of POSA/DFI.

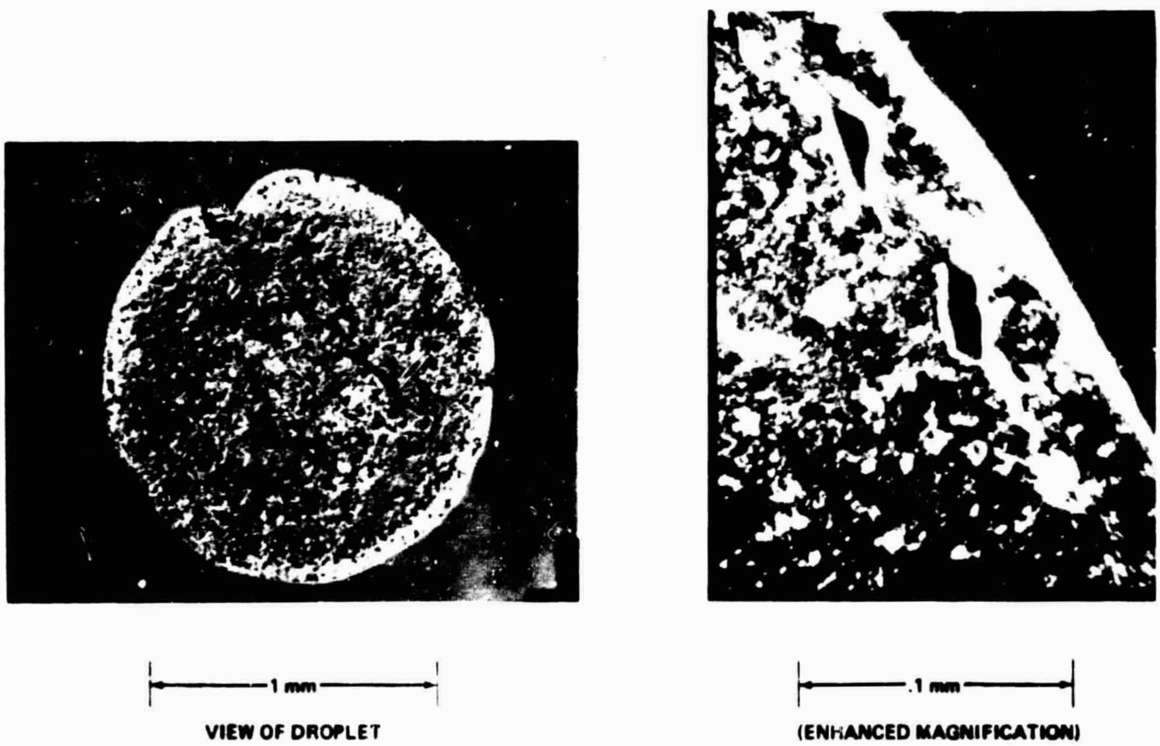


Figure 11. Phase-contrast microphotographs of droplet (residue) on sample A (MgF_2/Al) of POSA/DFI.

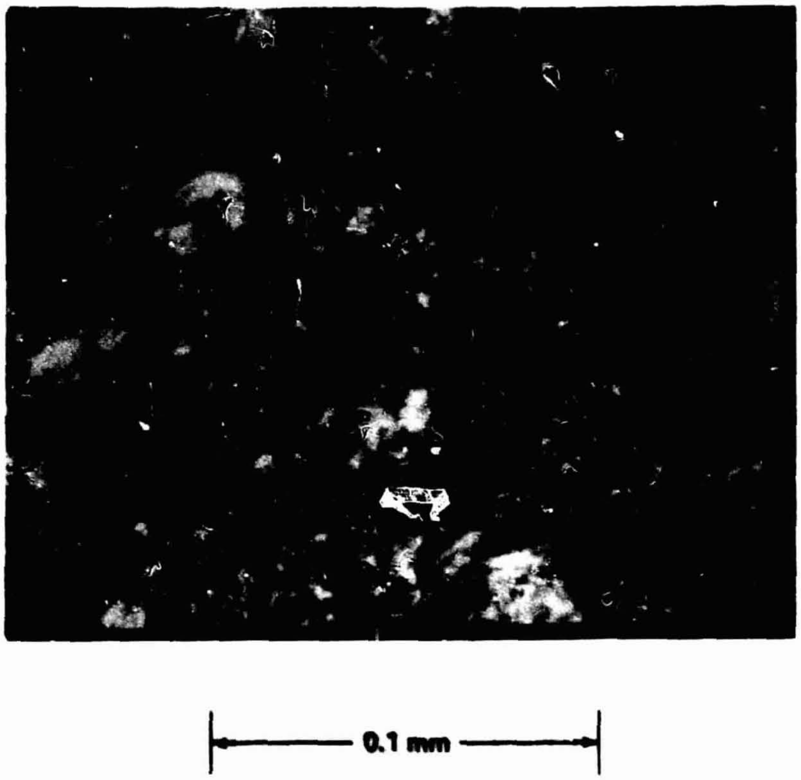
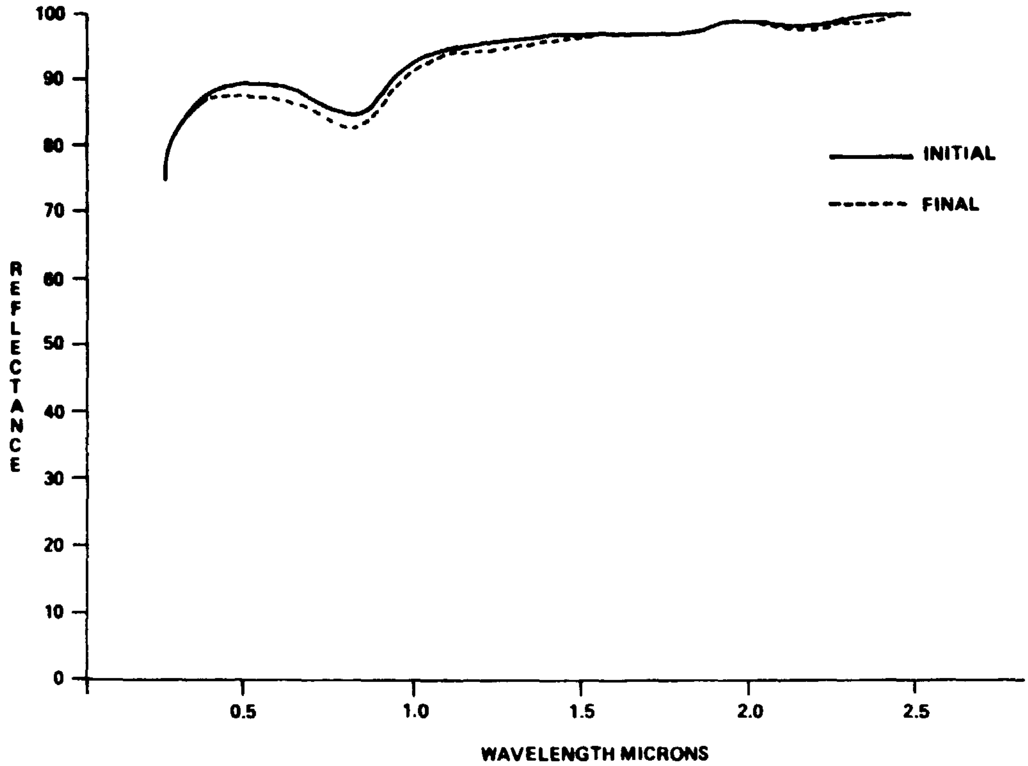


Figure 12. Enhanced magnification phase/contrast microphotograph of "smudge" on sample A (MgF_2/Al) of POSA/DFI.

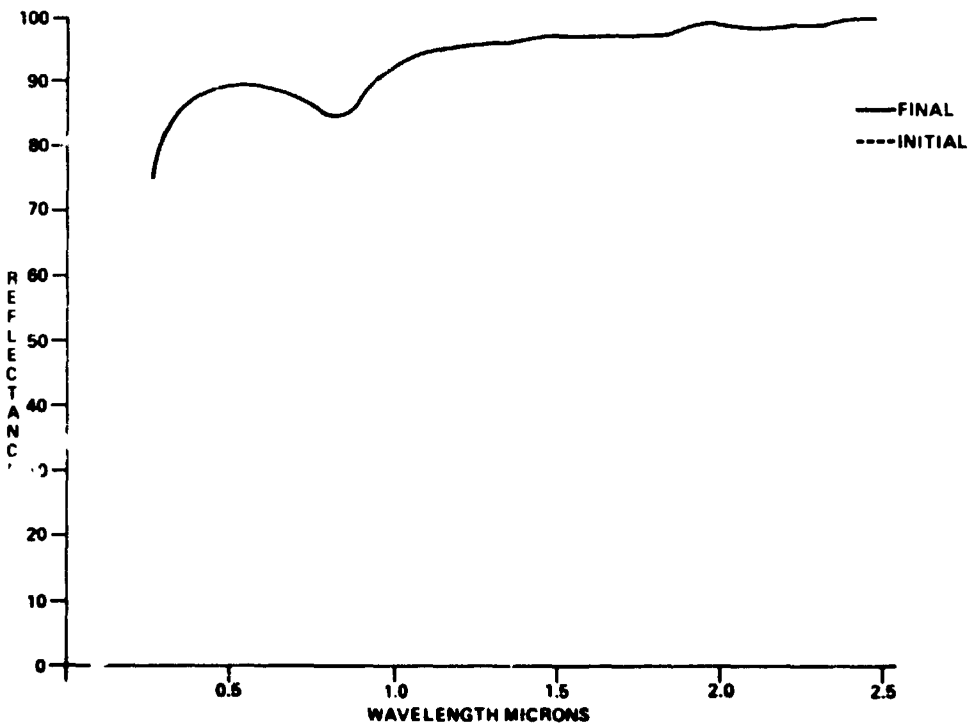
The results of the vacuum ultraviolet measurements of specular, spectral reflectance and transmittance are shown in Figures 15 through 28. A tabulated summary of these results is listed in Table 3. For each Optical sample of each POSA unit, the curves show the postflight changes in the measured optical properties, and additionally, on separate graphs, show the computed percent changes for assessing the significance of indicated degradation. The reflectance, and percent changes in reflectance, of the narrow band ultraviolet filters (Samples C of both POSA units) were included simply to extend the spectral range of investigation (Figs. 21 and 23).

From these data some general conclusions can be readily inferred:

The reflectance and the percent change in reflectance of the MgF_2/Al mirror of POSA/DFI indicate a uniform 10 percent relative decrease from preflight levels, in general agreement with the diffuse reflectance results. For the ferry flight MgF_2/Al mirror, the indicated degradation is less over most of the wavelength range, with evidence of some spectral effects (Fig. 16). The absence of spectral effects in the POSA/DFI MgF_2/Al mirror may be attributed to light scattering from the smudge and droplet, masking any interference effects that may be present. A significant increase in backscatter on the smudged mirror was detected by the Gier Dunkle/Beckman facility at longer wavelengths.

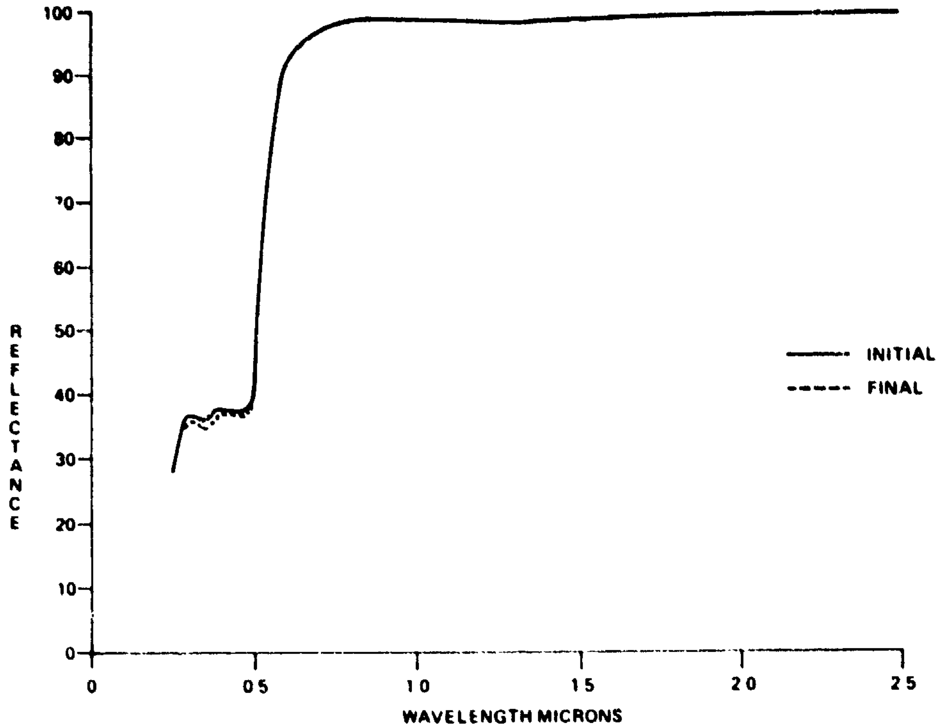


a. POSA/DFI sample.

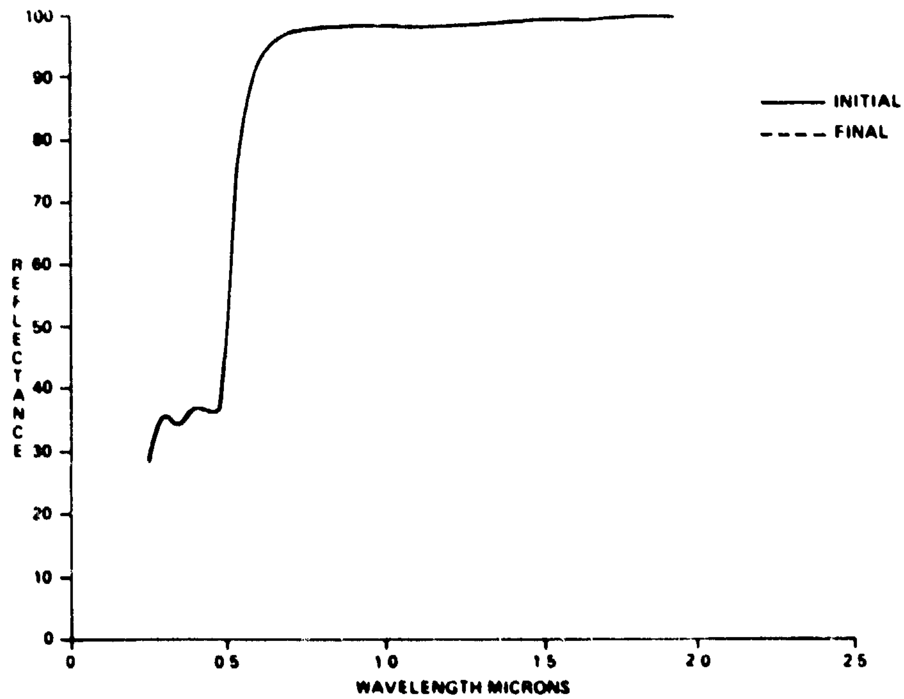


b. POSA/FF sample.

Figure 13. Optical results: sample MgF_2/Al, position A.



a. POSA/DFI sample.



b. POSA/FF sample.

Figure 14. Optical results: gold sample, position B.

TABLE 3. SUMMARY OF POSA OPTICAL RESULTS.

SAMPLE	POSA/DFI %Δ	POSA/FF %Δ
MgF_2/Al	Reflectance: -10%	Reflectance: -10%
Gold	Reflectance: -16%	Reflectance: -15%
UV Filter	Transmittance: ±10% Reflectance: -25% to +9%	Transmittance: -10% to +14% Reflectance: -21% to +8%
	1810 Å Filter	1790 Å Filter
"Window" Position D	Transmittance: ±2% (CaF_2)	Transmittance: ±2% (SiO_2)
"Window" Position E	Transmittance: -8% to +6% (CaF_2)	Transmittance: -5% to +2% (CaF_2)

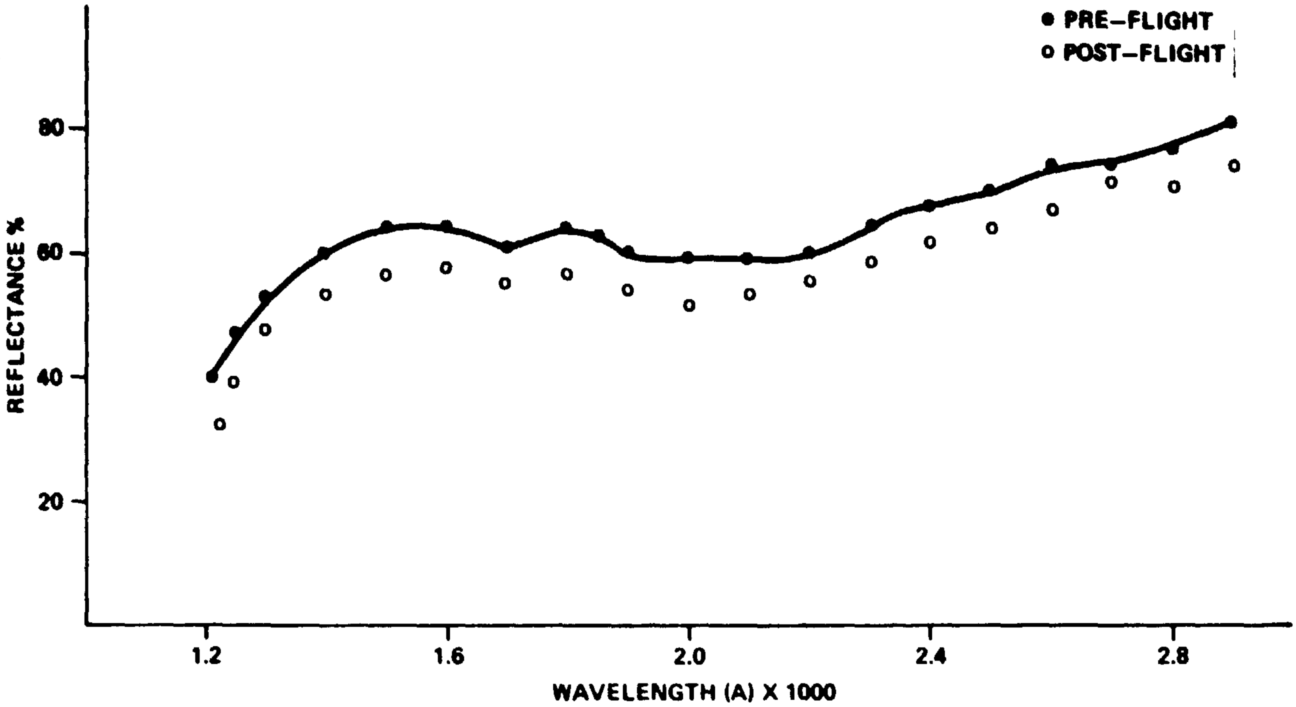
%Δ = Maximum percent change in reflectance in range 120 - 2500 nm.

For the reverse side of the MgF_2/Al mirror of POSA/DFI (Fig. 17), the data indicate significant changes below 1700 Å (∿ 10 percent), with no apparent degradation at higher wavelengths. The comparable results for the MgF_2/Al mirror of POSA/FF indicate no apparent change throughout the measured spectral range. The most likely source of contamination for the reverse side of these samples is the paint-coated surface of the DFI pallet strut to which the POSA was mounted (offset). This paint was Chem-Glaze A8-276, an acrylic polyurethane coating with titanium oxide (TiO_2).

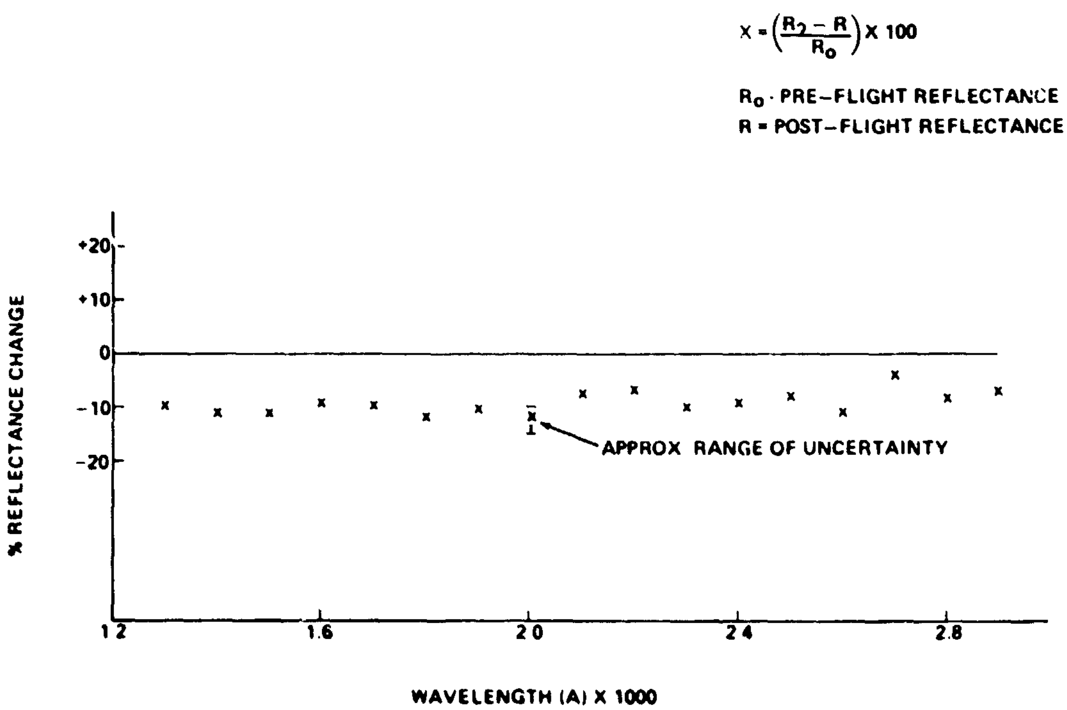
Results of the gold mirrors of both POSA units (Figs. 18 and 19) indicate similar change (approximately 10 percent decrease in reflectance, relative), with the range of uncertainty masking any possible significant differences. There is, again considering the uncertainty, little significant change at wavelengths greater than 2400 Angstroms, confirming the results of the diffuse data from the Beckman DK-2 facility.

The results for the vacuum ultraviolet filters (∿200 Å bandwidth) indicate no significant change in the transmittance for the filter of either POSA unit, considering the uncertainty (Figs. 20 and 22). The front surface reflectance of these filters indicates measureable degradation, although the greater change occurred in the region of lower front-surface reflectance (transmissive bandwidth) and is subject to greater uncertainty due to the lower initial magnitude of reflectance.

There is generally no significant change in the optical properties of any of the transparent samples (CaF_2, fused silica) of either POSA unit, with the exception of the reflectance of the reverse side of the CaF_2 sample in position D of POSA/DFI; there was no apparent change in the reverse-side reflectance of the comparable sample in POSA/FF.

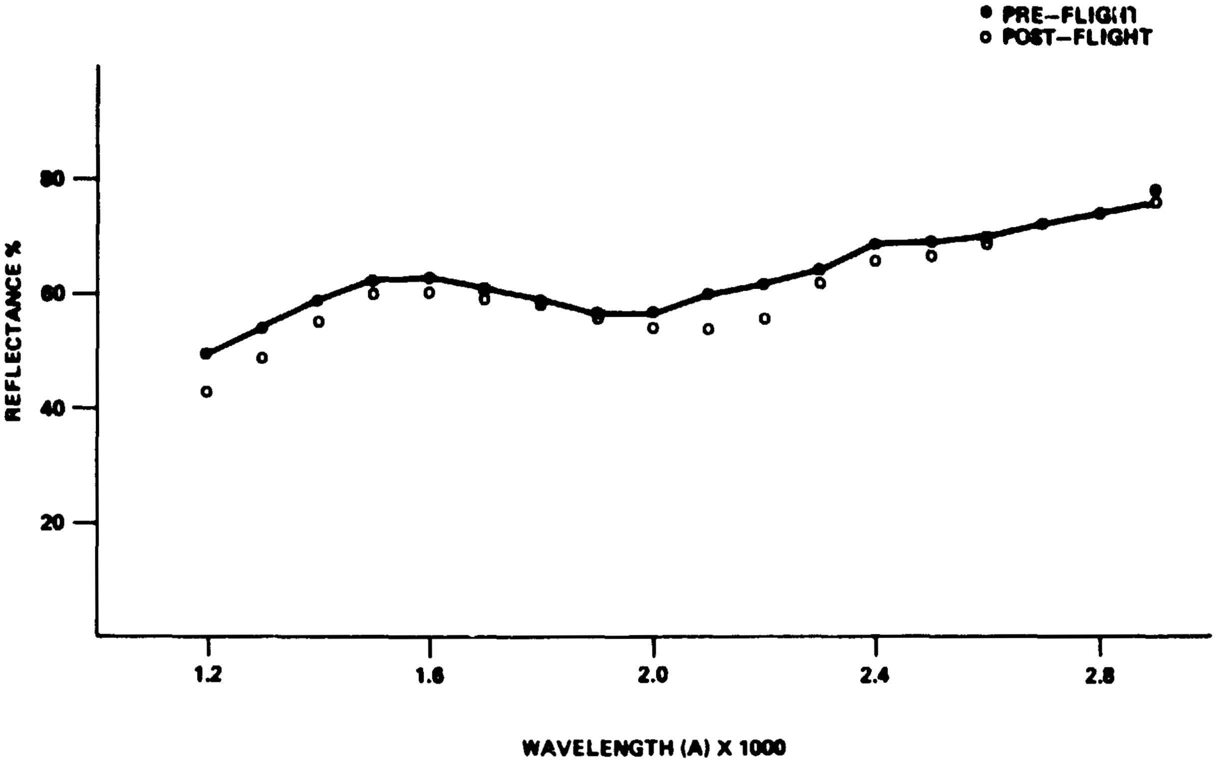


a. Reflectance measurements.



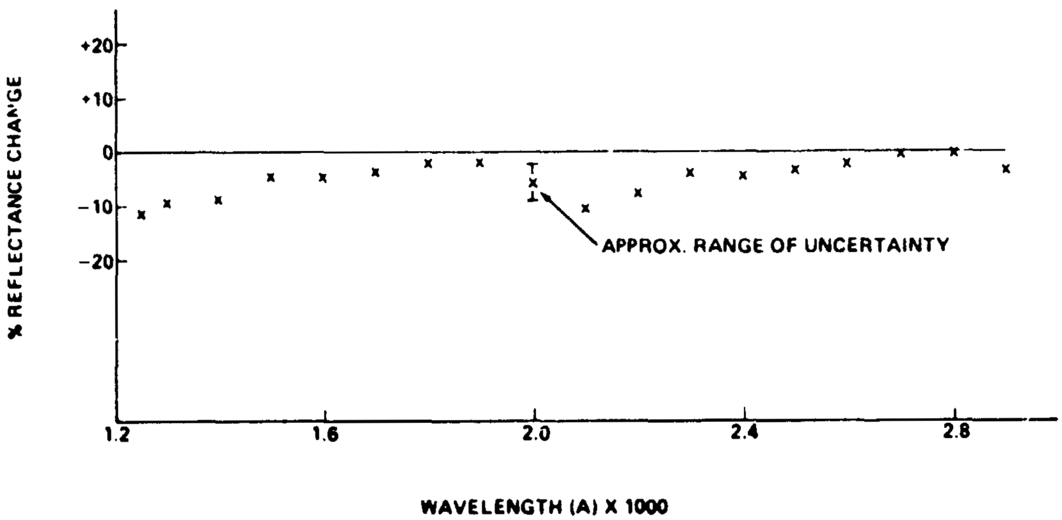
b. Calculated percent change in reflectance.

Figure 15. POSA/DFI sample MgF_2/Al, position A.



a. Reflectance measurements.

$$X = \left(\frac{R_o - R}{R_o}\right) \times 100$$



b. Calculated percent change in reflectance.

Figure 16. POSA/FF sample MgF_2/Al, position A.

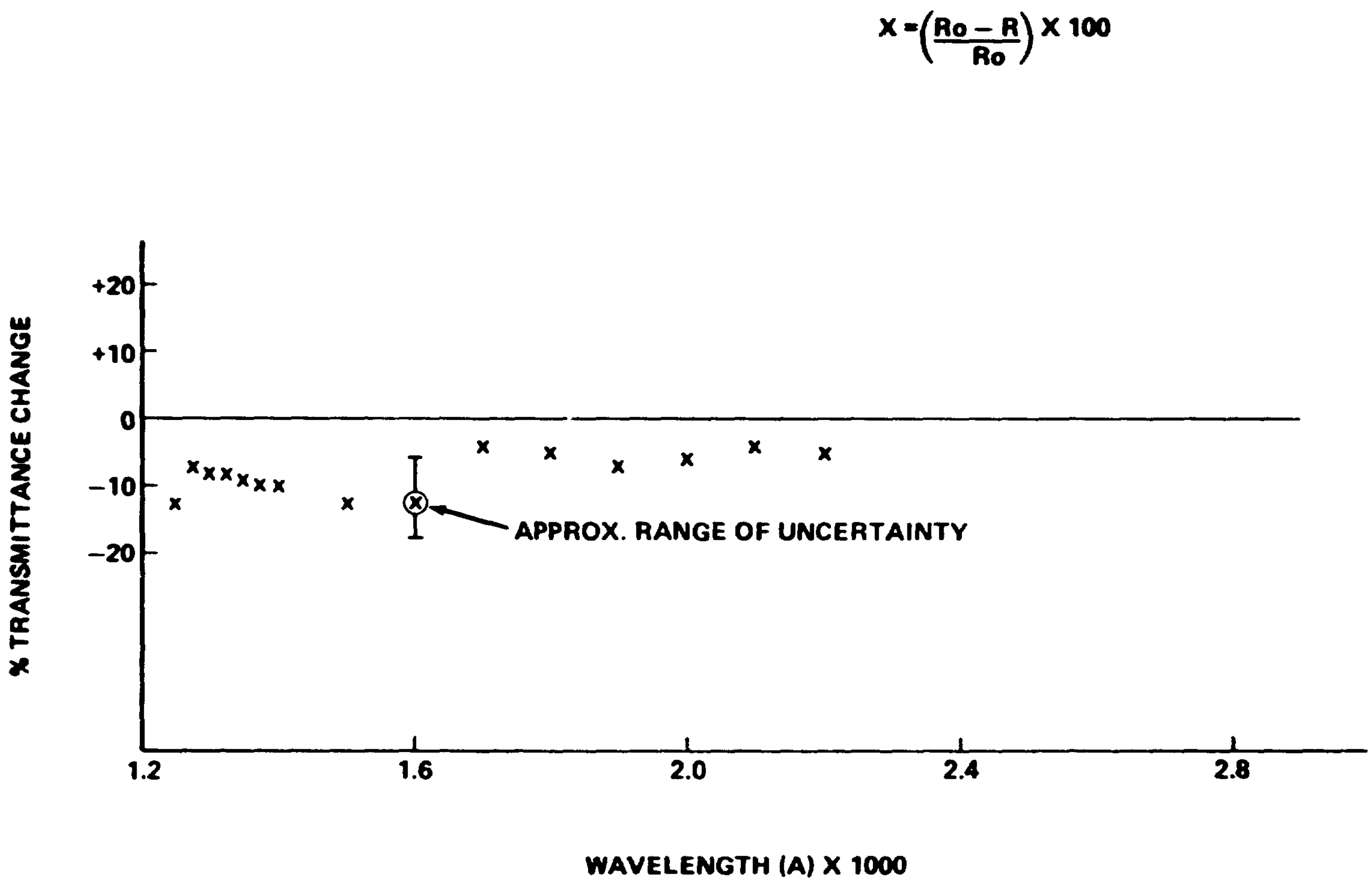
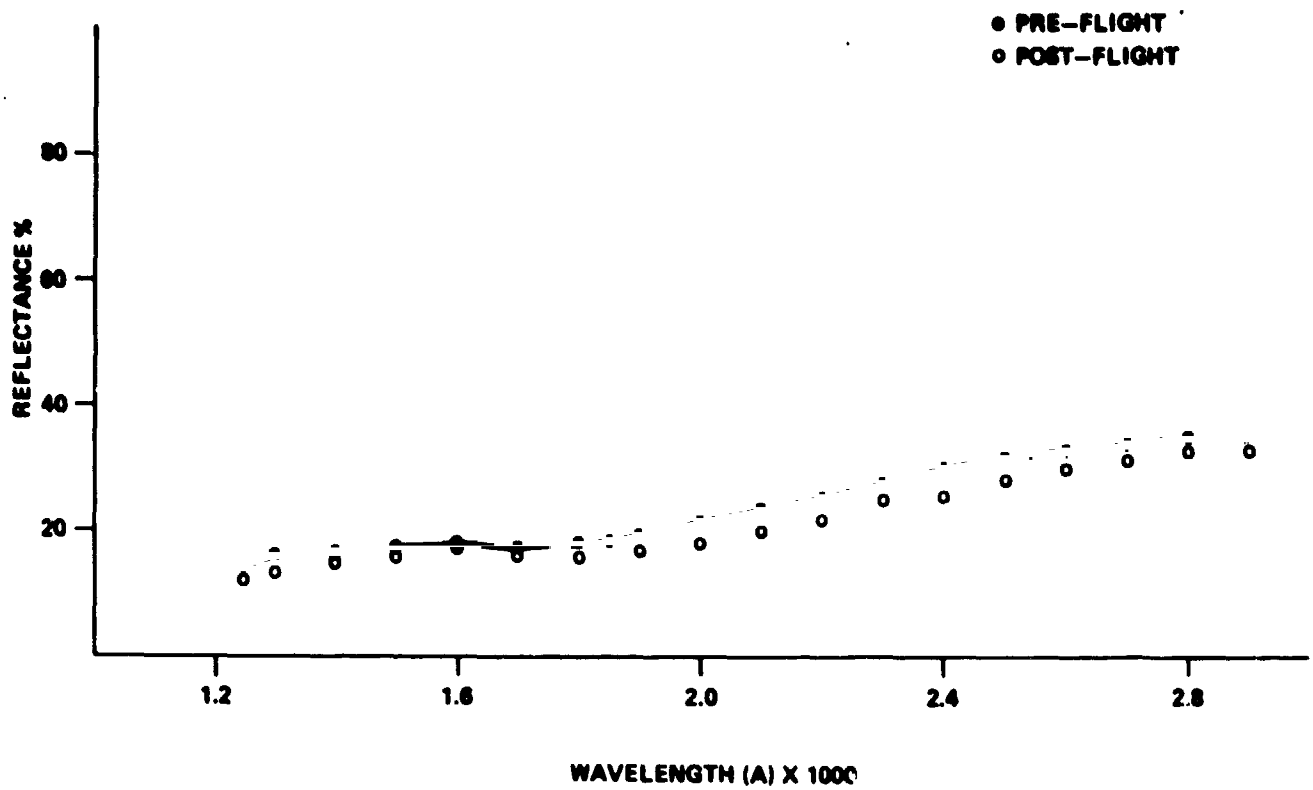
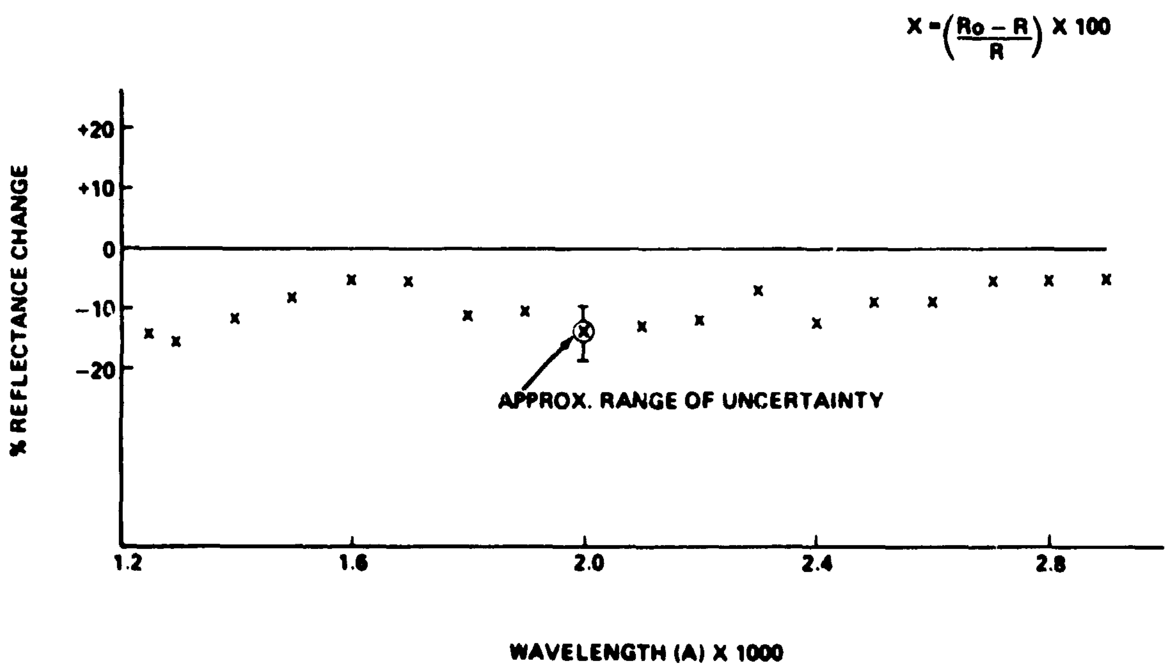


Figure 17. POSA/DFI sample MgF_2/Al, reverse side (-Z) facing DFI pallet strut.

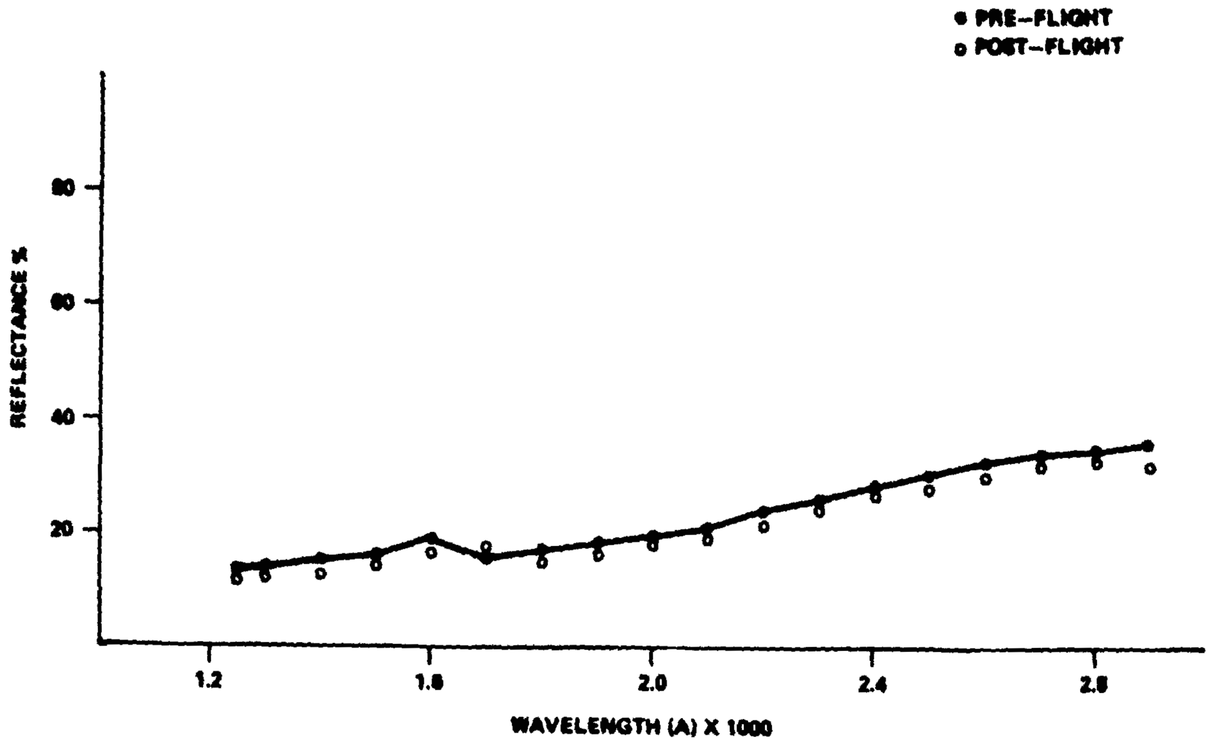


a. Reflectance measurements.

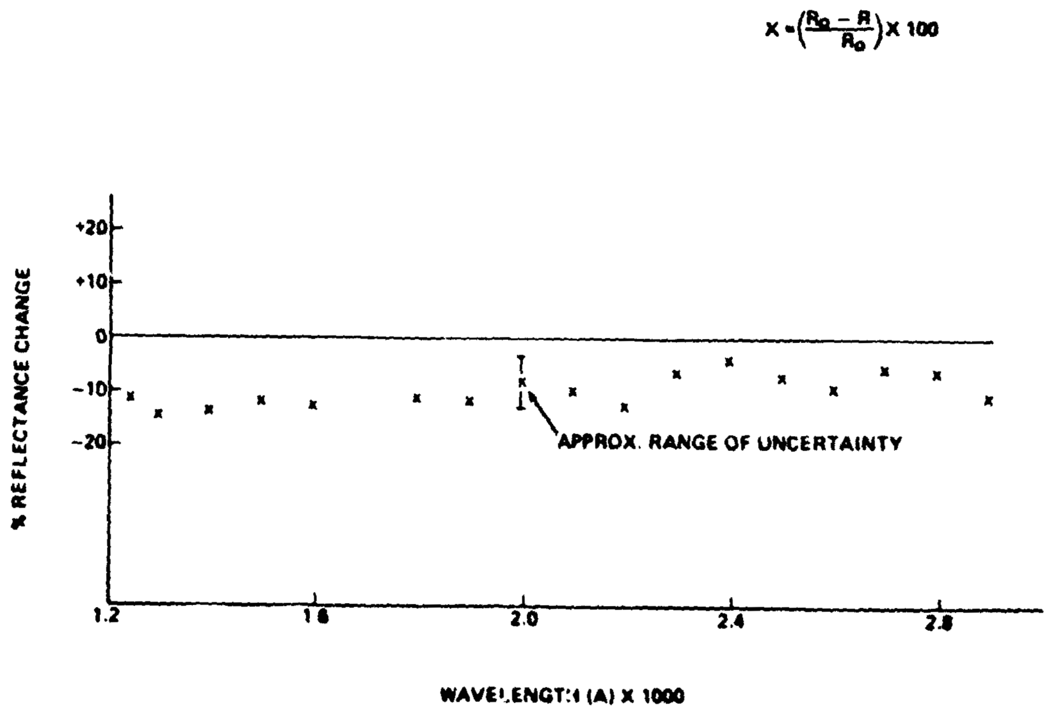


b. Calculated percent change in reflectance.

Figure 18. POSA/DFI gold sample, position B.

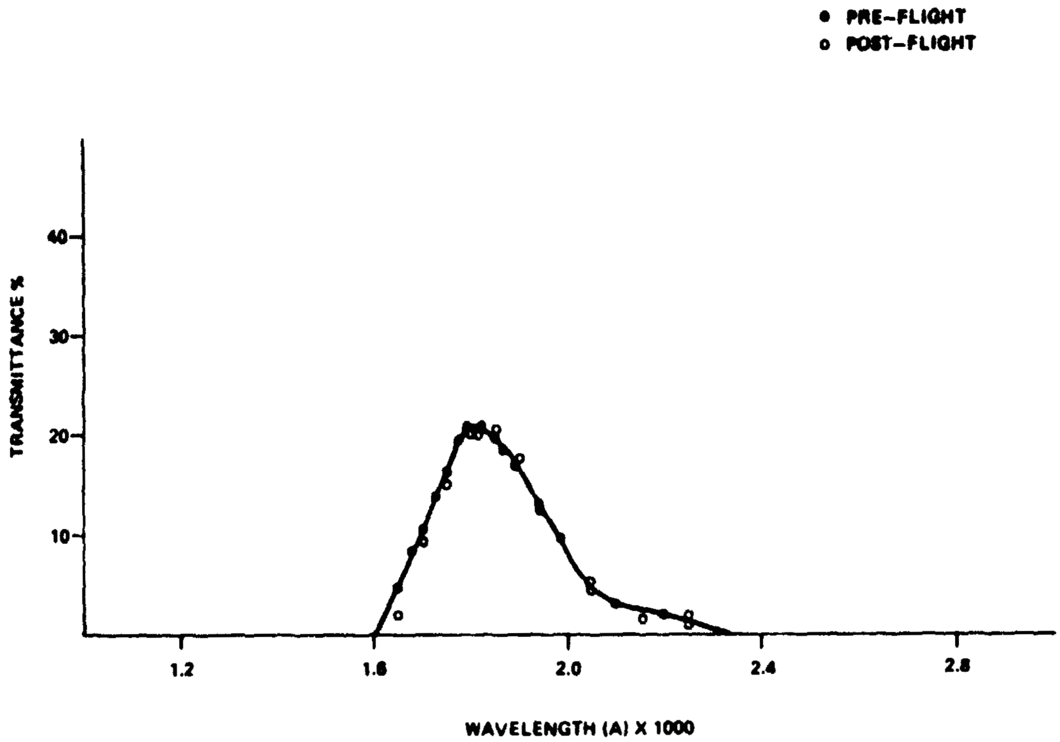


a. Reflectance measurements.

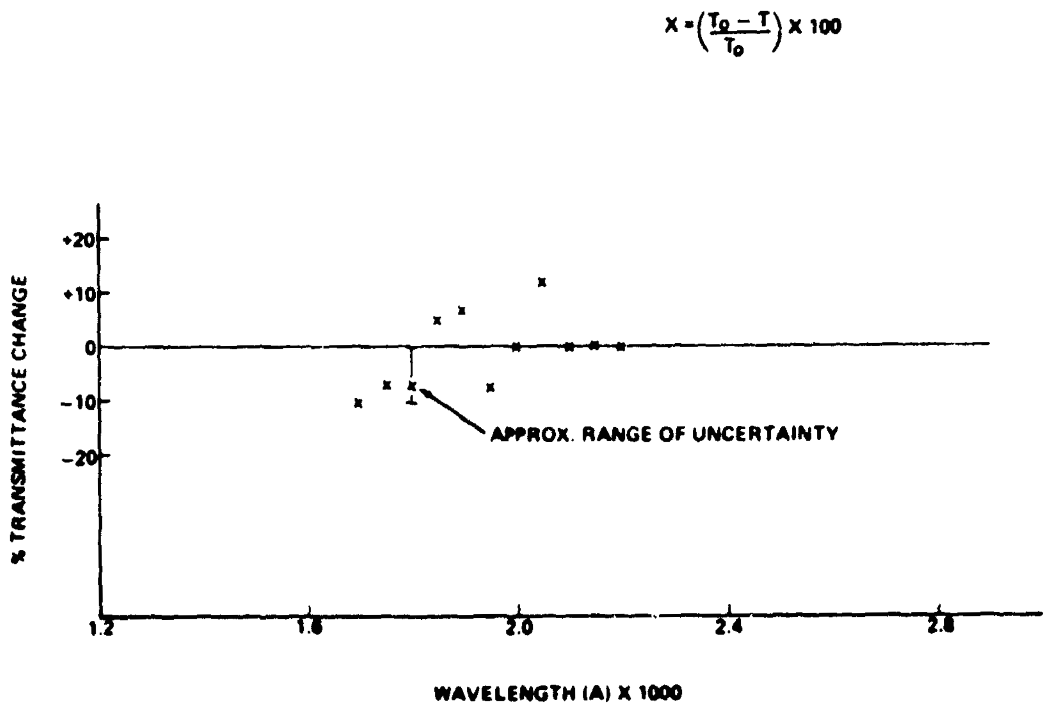


b. Calculated percent change in reflectance.

Figure 19. POSA/FF gold sample, position B.

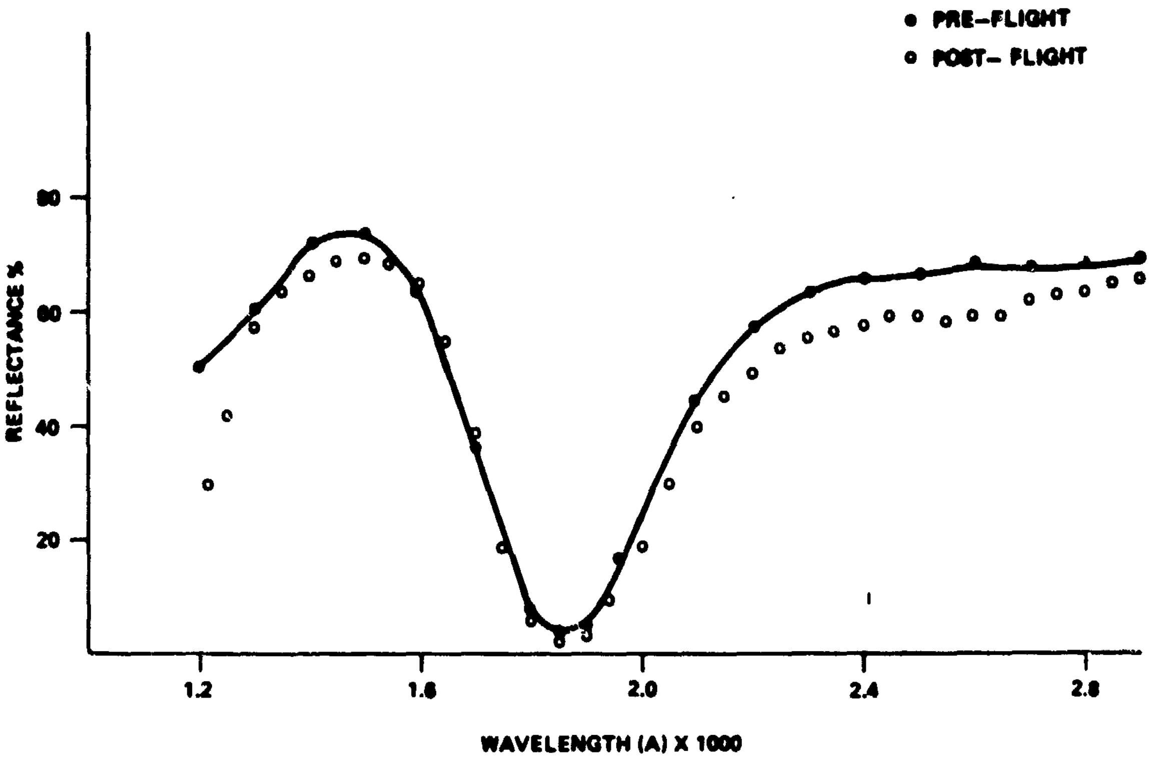


a. Transmittance measurements.



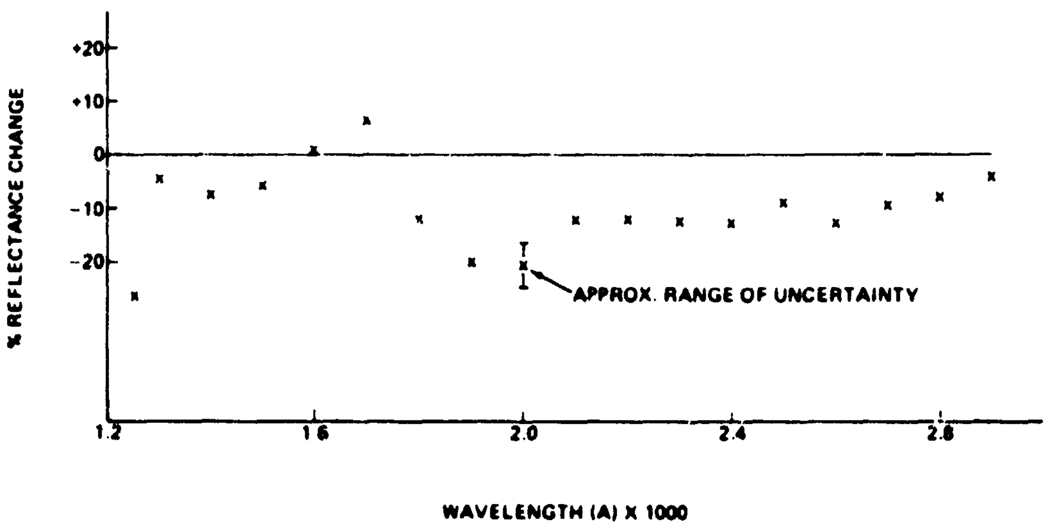
b. Calculated percent change in transmittance.

Figure 20. POSA/DFI sample: 1810 Å filter, position C.



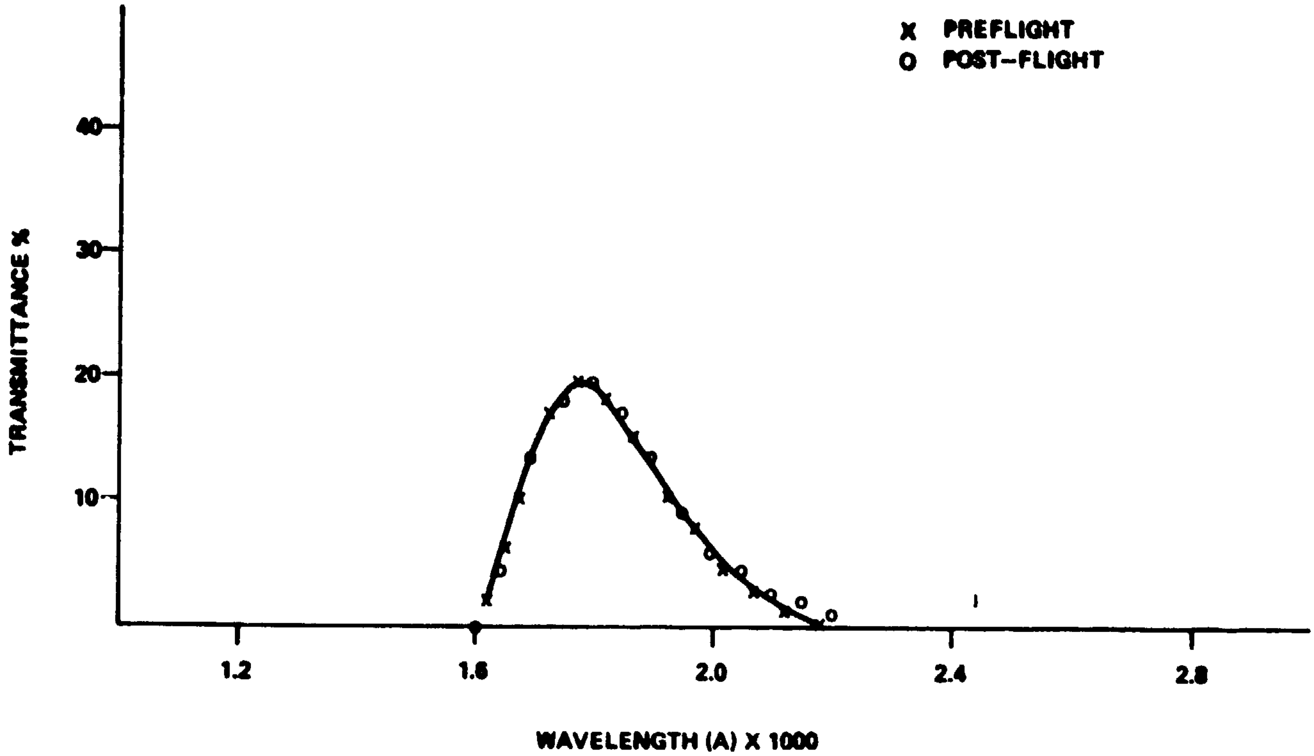
a. Reflectance measurements.

$$X = \left(\frac{R_o - R}{R_o}\right) \times 100$$

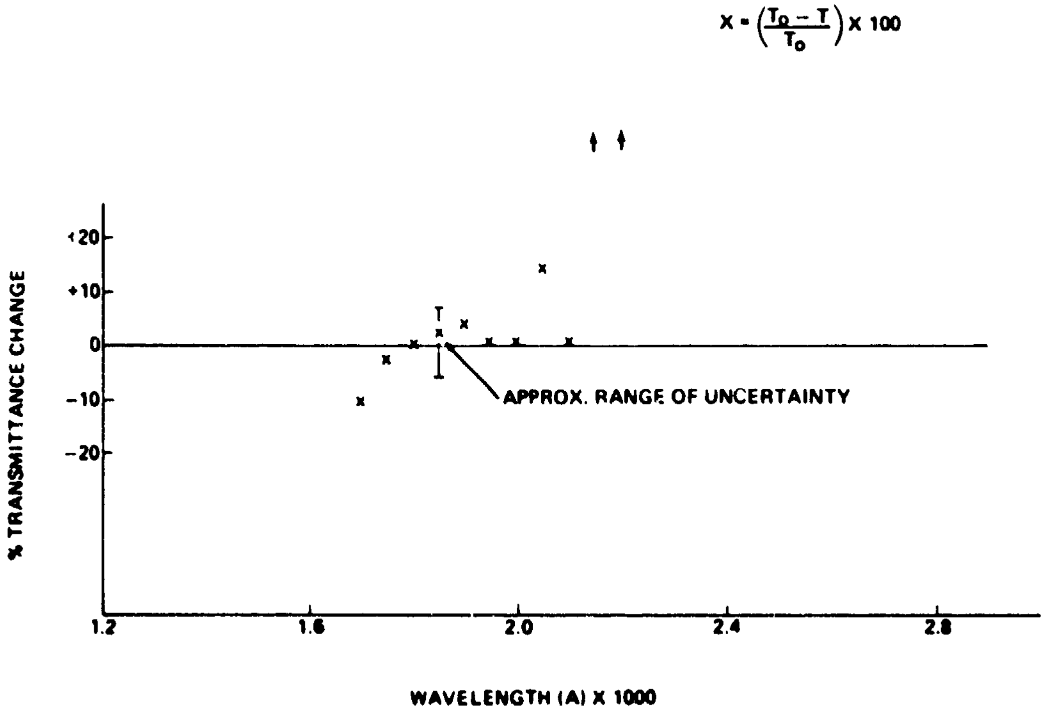


b. Calculated percent change in reflectance.

Figure 21. POSA/DFI sample: 1810 Å filter, position C.

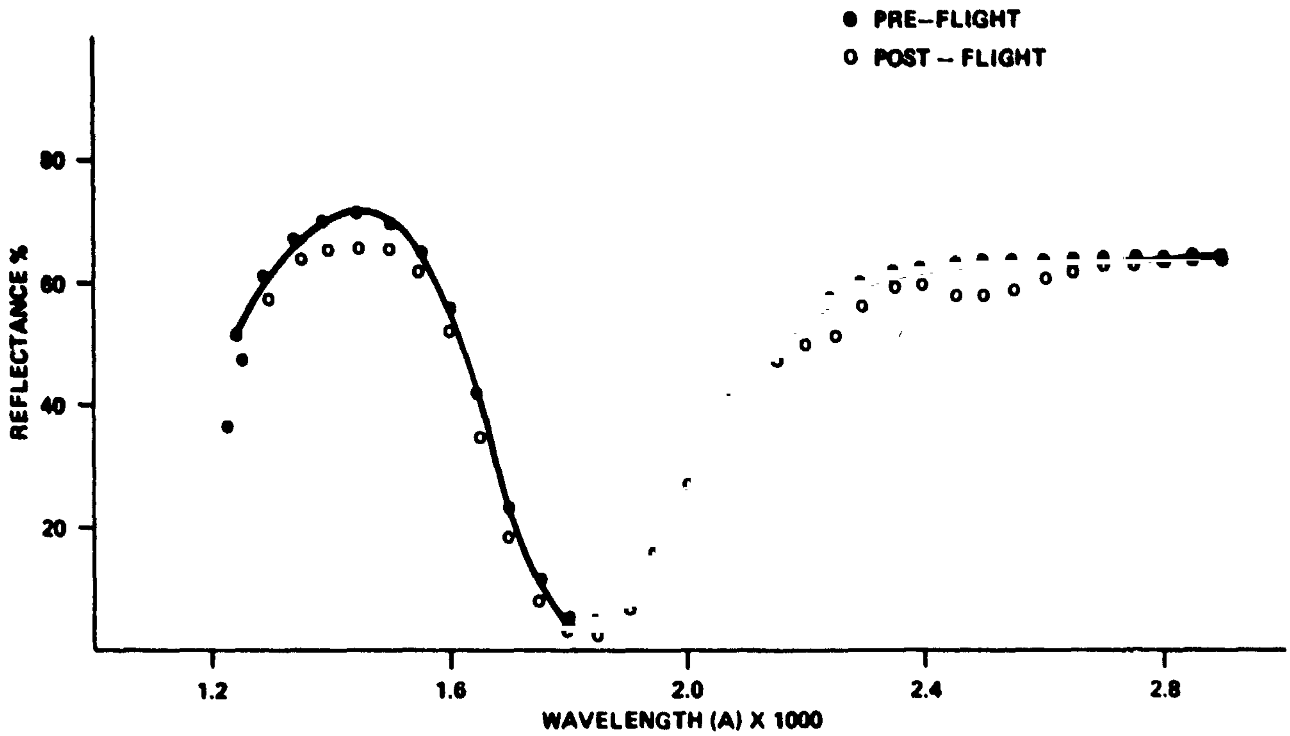


a. Transmittance measurements.

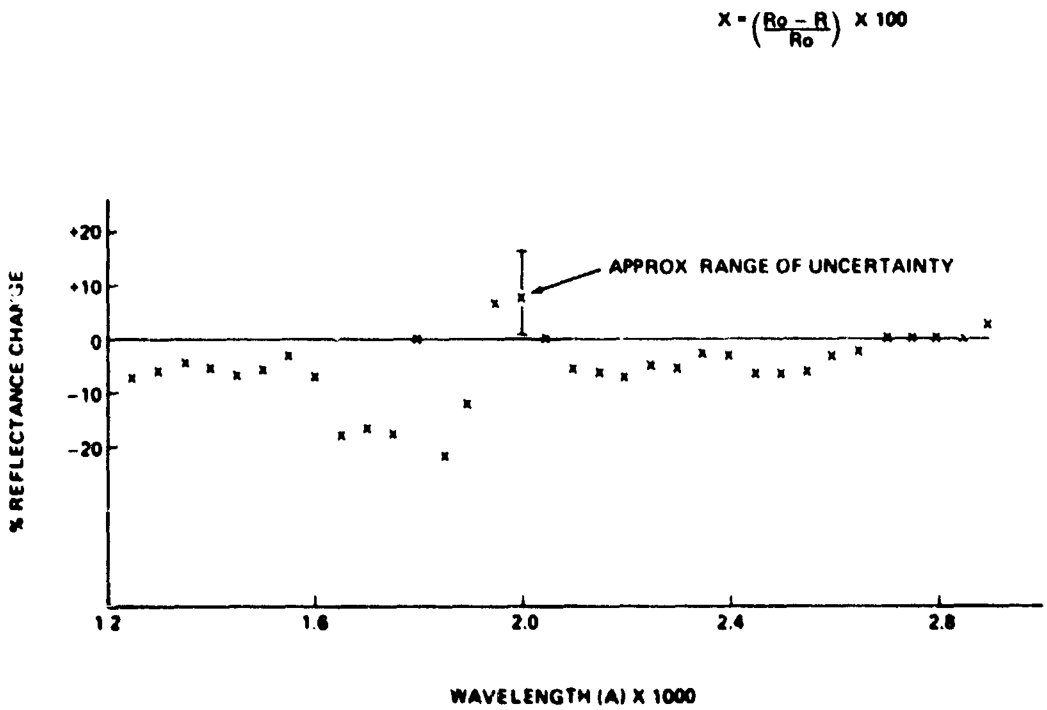


b. Calculated percent change in transmittance.

Figure 22. POSA/FF sample: 1790 Å filter, position C.

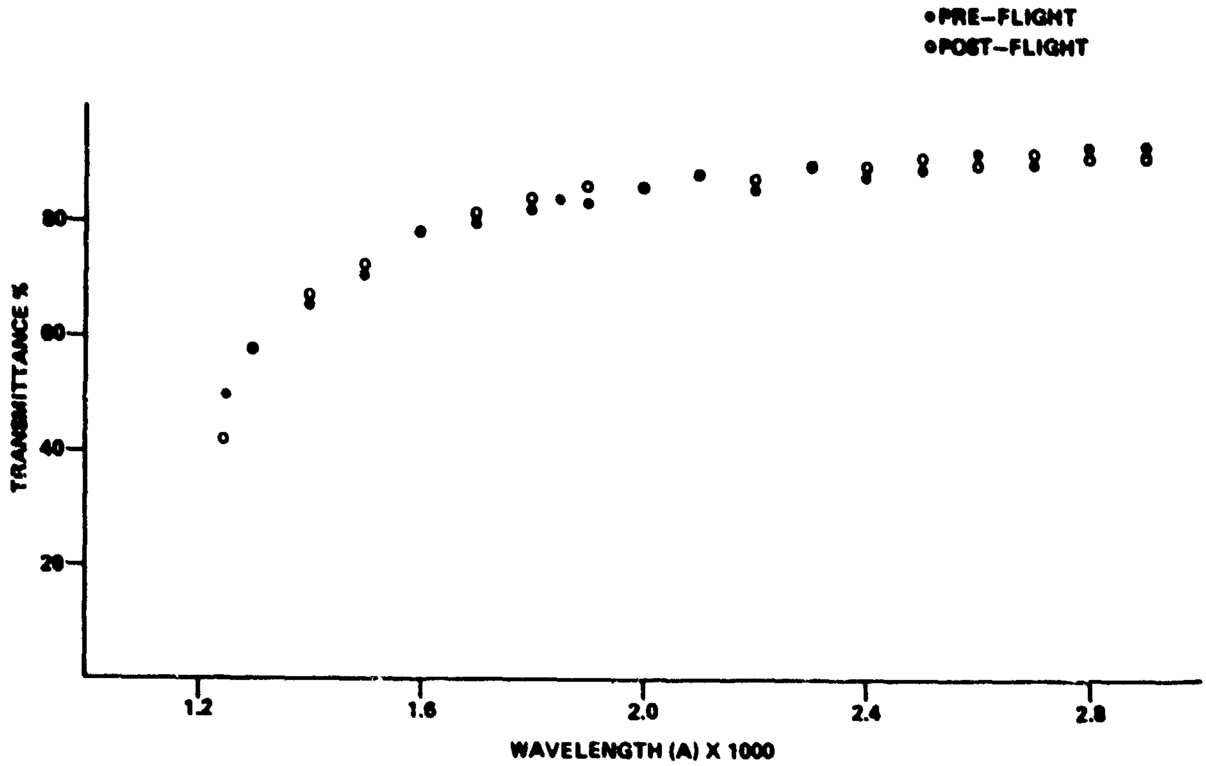


a. Reflectance measurements.

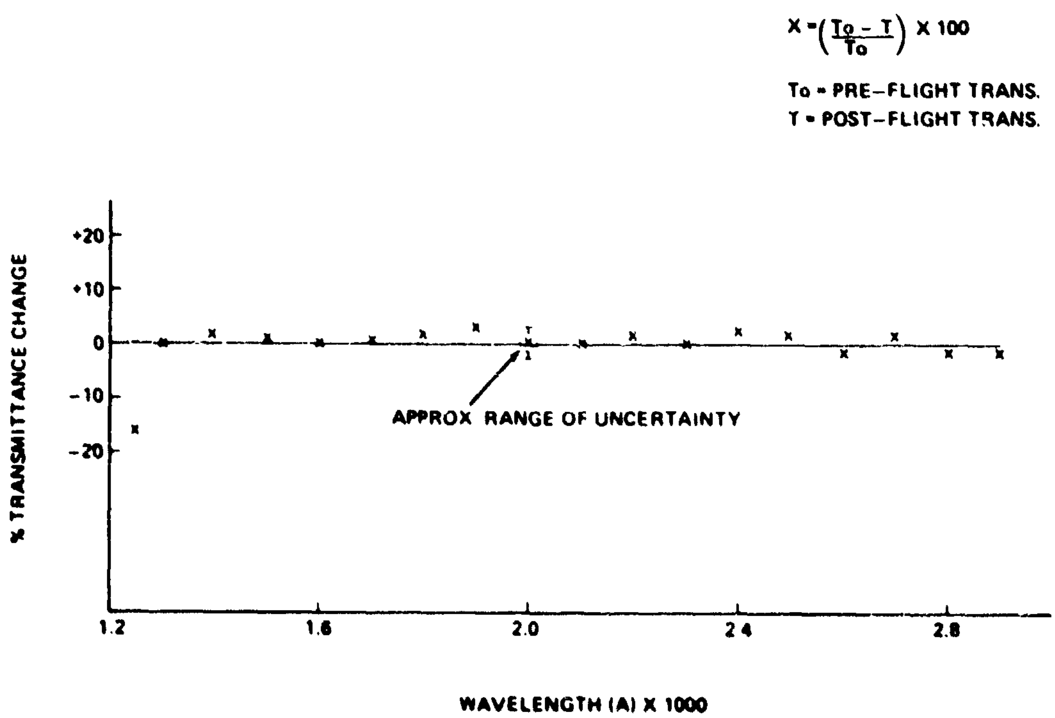


b. Calculated percent change in reflectance.

Figure 23. POSA/FF sample: 1790 Å filter, position C.

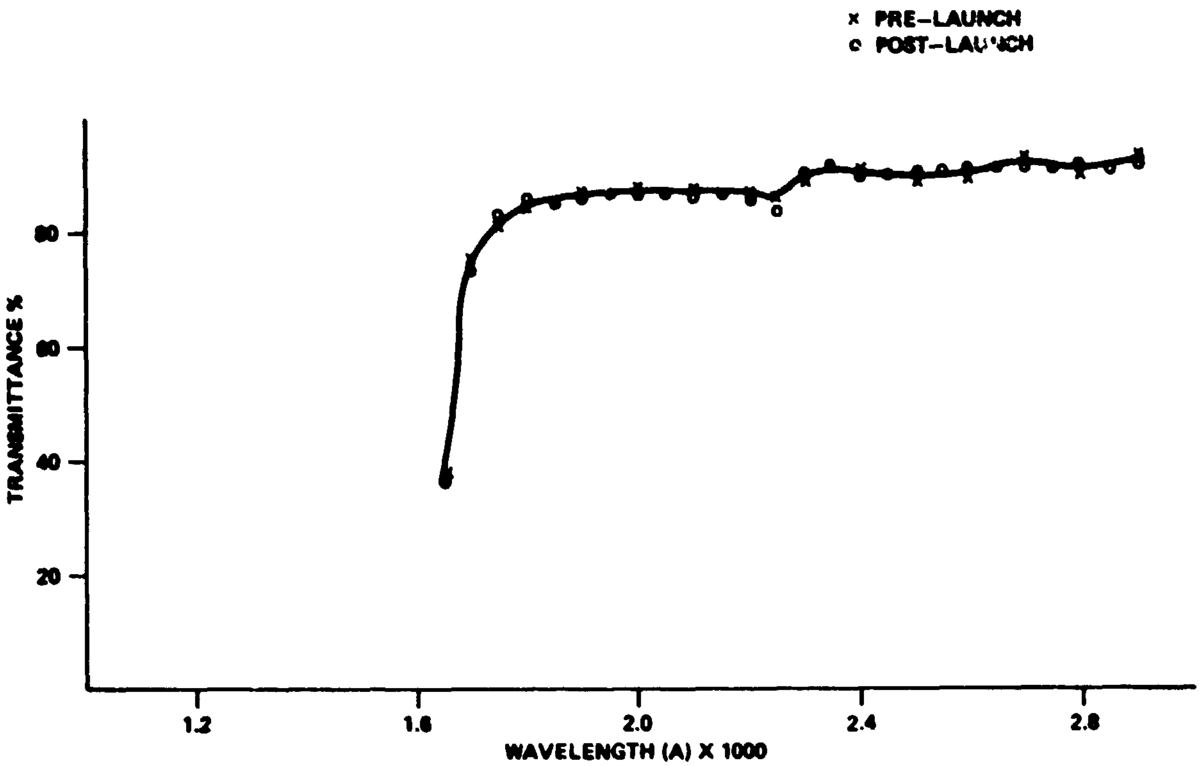


a. Transmittance measurements.



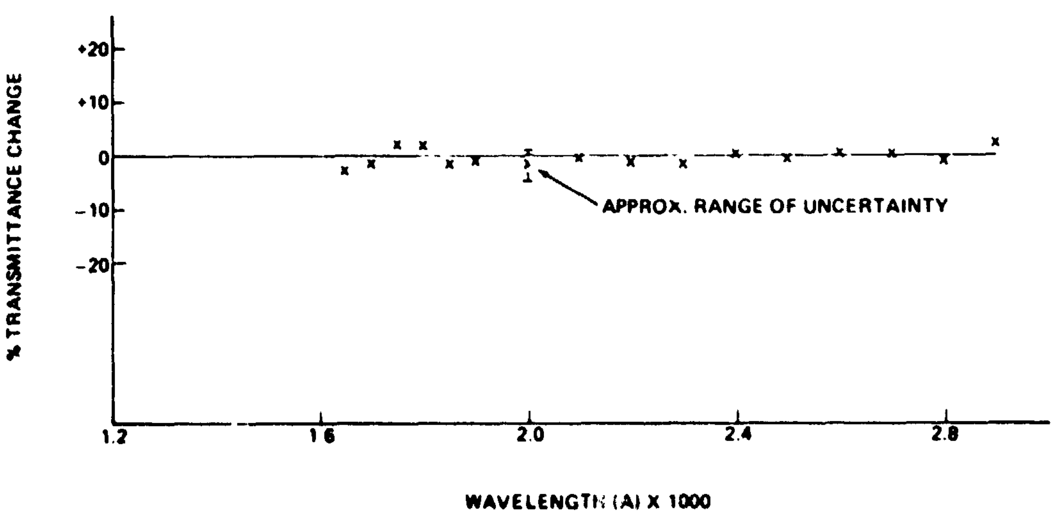
b. Calculated percent change in transmittance.

Figure 24. POSA/DFI sample: CaF_2 No. 2, position D.



a. Transmittance measurements.

$$X = \left(\frac{T_o - T}{T_o}\right) \times 100$$



b. Calculated percent change in transmittance.

Figure 25. POSA/FF sample: fused silica, position D.

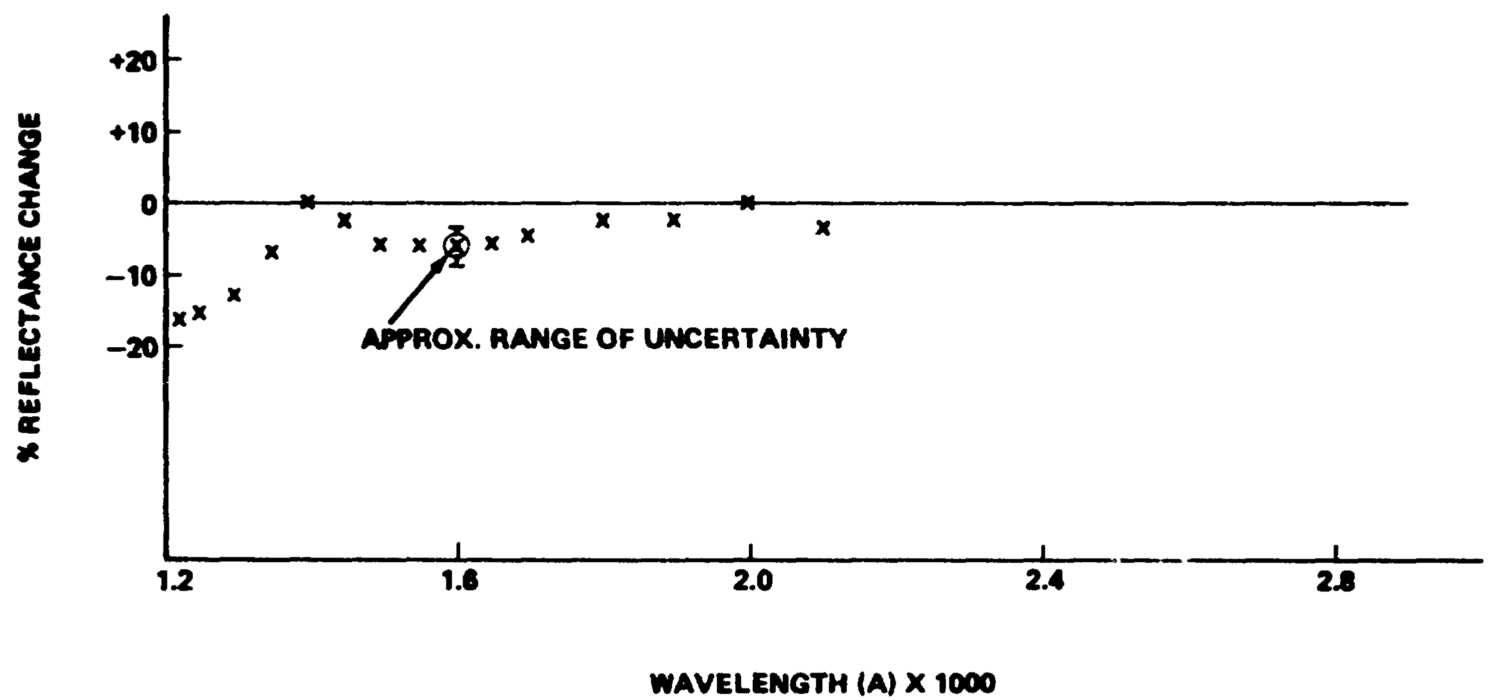
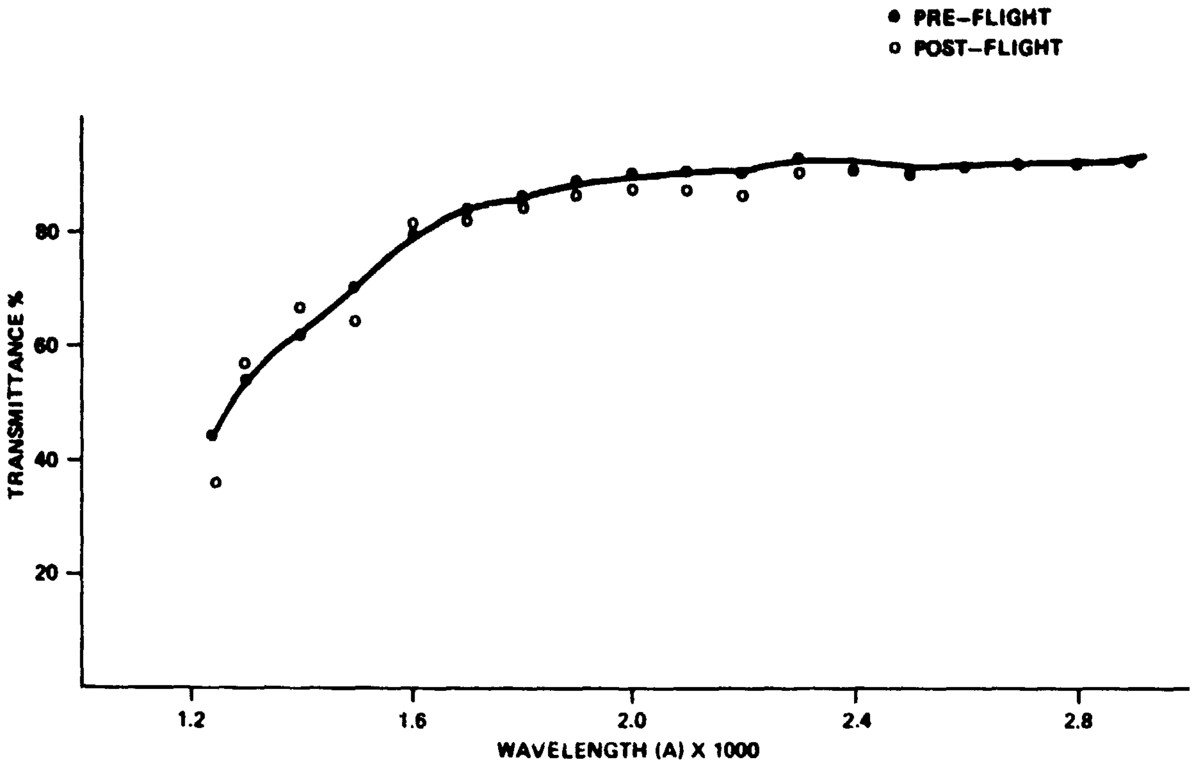
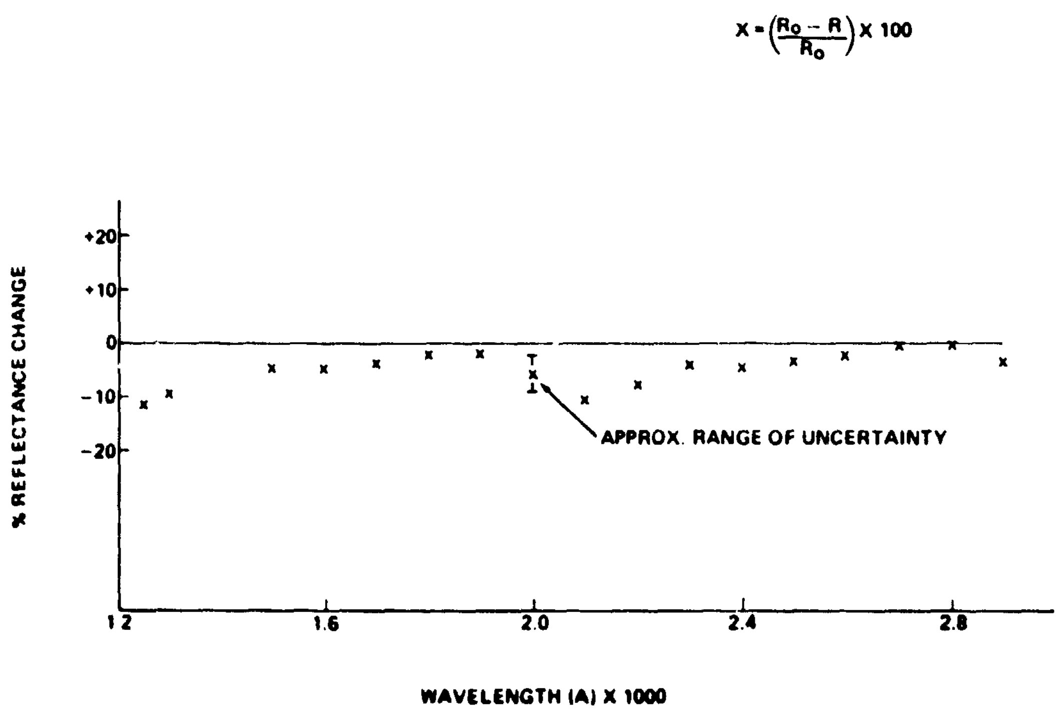


Figure 26. POSA/DFI sample: CaF_2, reverse side (-Z), facing DFI pallet strut.

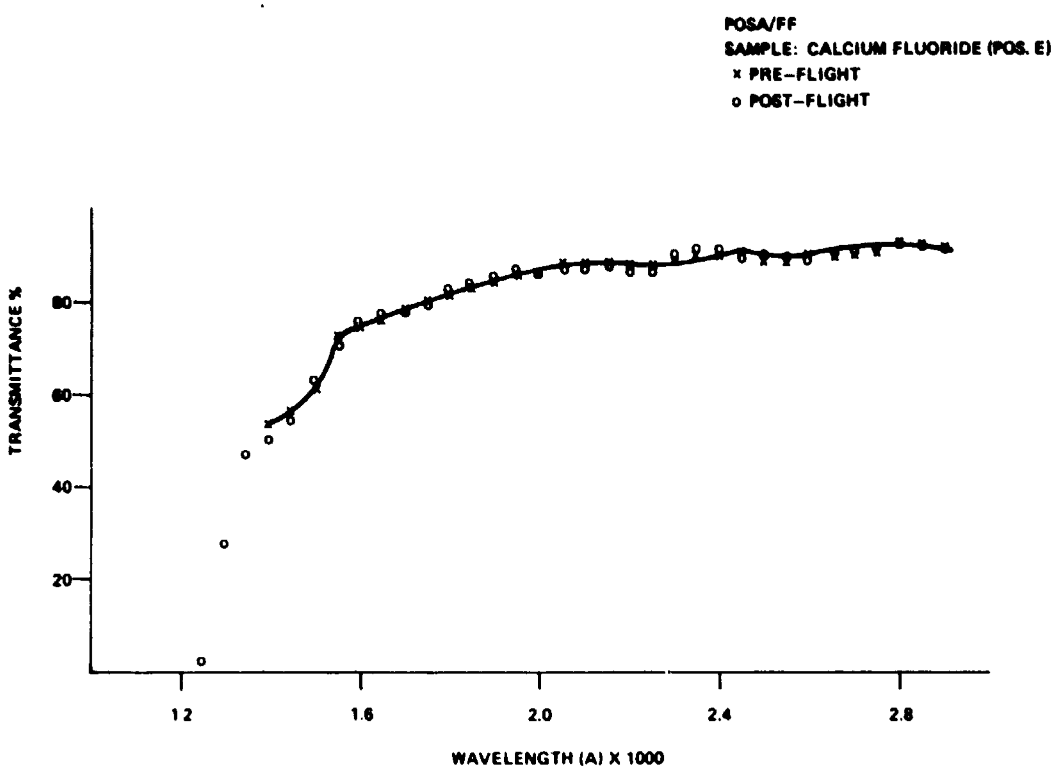


a. Transmittance measurements.

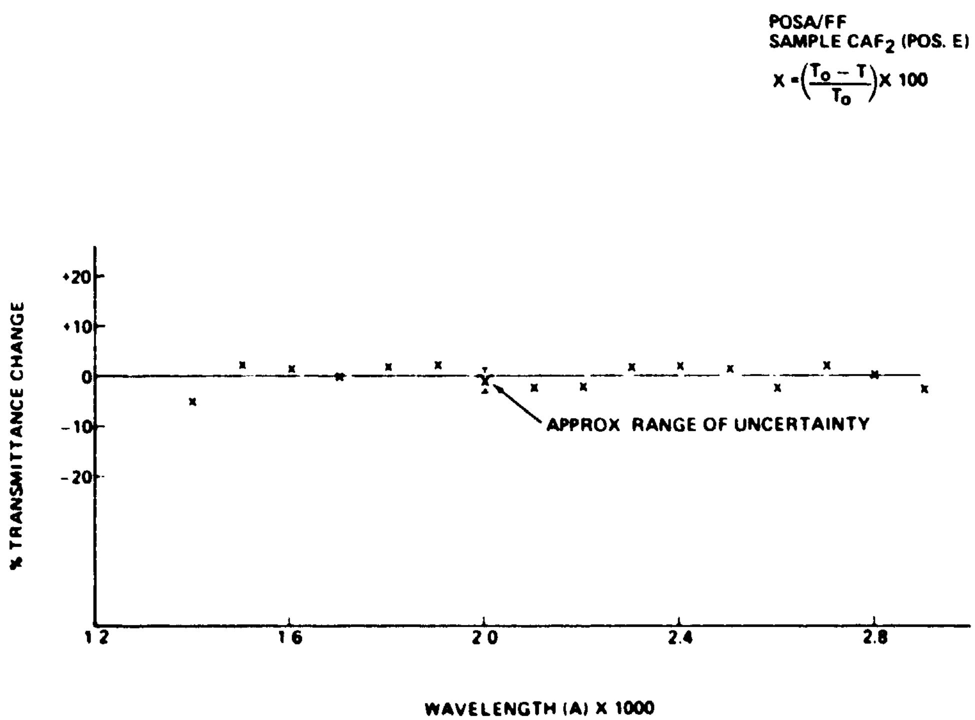


b. Calculated percent change in transmittance.

Figure 27. POSA/DFI sample: CaF_2, position E.



a. Transmittance measurements.



b. Calculated percent change in transmittance.

Figure 28. POSA/FF sample: CaF_2, position E.

SUMMARY OF CONCLUSIONS - VACUUM ULTRAVIOLET OPTICAL RESULTS

Measurable degradation in the optical properties of the reflecting samples was detected for both POSA units.

No measurable degradation was detected for the transmissive samples.

Generally, the change in reflectance was slightly greater for samples of the POSA/DFI than for samples restricted to the ferry flight.

There was evidence of measurable degradation due to outgassing of the paint on the DFI pallet strut.

RESULTS - PARTICLE ANALYSIS OF OPTICAL SAMPLES

The quantity and size distribution of particles on some of the samples of both POSA units have been measured using a white light, imaging, particle counting facility.[1] These data include comparison scans of similar samples from the POSA/DFI unit and the POSA/FF unit. For all the samples, the results uniformly indicate a size distribution heavily weighted toward particles less than 10 μm in diameter, with the greater number of these less than 5 μm in diameter. The results indicate further, that the type of sample surface may have a considerable influence on the number of adhering particles; particle counts on the ultraviolet filters of both POSA units exceed $10^5/cm^2$ for particle diameters less than 5 μm, while the comparable statistics for the other samples were lower by a factor of 10^3.

Preflight particle scans indicated an average count of 90 particles/cm^2 on the samples, with diameters < 10 μm. An updated summary of the results of the particle distribution measurements, restricted for particles of diameter less than 10 μm, is shown in Table 4. With reference to the earlier quick-look report [2], the differences in these results are attributed to the greater accuracy of count achieved by scanning larger areas of each sample in repeat measurements. These results confirm that, while all samples of both POSA units collected measurable levels of particles, nearly all of the samples of POSA/DFI were denser in particle distributions. The more detailed results, providing relative population densities for particle size ranges up to 1000 μm in diameter, are given in Tables 5 through 9. These results indicate no significant variations in the relative population distributions for samples of either POSA unit.

The large difference in particle populations on the ultraviolet filters when compared to other POSA samples remains puzzling, although all of the results show some variations in adherence dependent on the sample type. The results did not change when particle distribution measurements were repeated on all samples. Residual charge on all of the POSA samples (and POSA control samples) was measured with a Keithley Model 6103 electrometer to see if this could account for the greater apparent particle "sticking" of the ultraviolet filters; the results indicated a surface charge of about $+10^{-10}$ Coulombs/cm^2 on the filters and the transparent POSA samples, with no charge

1. Bausch and Lomb Omnicon Automatic System, ES74, MSFC.

TABLE 4. POSA - PARTICLE DISTRIBUTION MEASUREMENTS.

PARTICLE SIZE $\leq$ 10 μm

SAMPLE	POSA/DFI COUNT	POSA/FF COUNT
A - MgF_2/Al	1866/cm^2	1263/cm^2
B - Cold	1075/cm^2	761/cm^2
C - UV filter	$1.4 \times 10^5/cm^2$	$1.37 \times 10^5/cm^2$
D - CaF_2(DFI)	1561/cm^2	906/cm^2
SiO_2(FF)		
E - CaF_2	1232/cm^2	126/cm^2

TABLE 5. POSA – PARTICLE DISTRIBUTION MEASUREMENTS.

POSA/DFI MgF_2/Al, Position A Total Area Scanned: 0.90 cm^2			POSA/FF MgF_2/Al, Position A Total Area Scanned: 2.83 cm^2		
Size Distribution (μm) Diameter	Particles/ (cm^2)	Relative Population	Size Distribution (μm) Diameter	Particles/ (cm^2)	Relative Population
0 - 2	259	:*****	0 - 2	69	:*
2 - 4	649	:************	2 - 4	395	:********
4 - 6	416	:********	4 - 6	266	:*****
6 - 8	223	:****	6 - 8	334	:*******
8 - 10	132	:**	8 - 10	199	:****
10 - 12	87	:*	10 - 12	203	:****
12 - 14	38	:	12 - 14	145	:***
14 - 16	75	:*	14 - 16	83	:*
16 - 18	23	:	16 - 18	44	:
18 - 20	20	:	18 - 20	34	:
20 - 22	22	:	20 - 22	23	:
22 24	10	:	22 - 24	16	:
24 - 26	25	:	24 - 26	16	:
26 - 28	†	:	26 - 28	3	:
28 - 30	4	:	28 - 30	10	:
30 - 32	17	:	30 - 32	9	:
32 - 34	6	:	32 - 34	1	:
34 - 36	5	:	34 - 36	3	:
36 - 38	6	:	36 - 38	4	:
38 - 40	5	:	38 - 40	3	:
40 - 50	10	:	40 - 50	7	:
50 - 100	15	:	50 - 100	10	:
100 - 500	2	:	100 - 500	1	:
500 - 1000	†	:	500 - 1000	0	:

†Invalid readings resulting from instrument error

TABLE 6. POSA – PARTICLE DISTRIBUTION MEASUREMENTS.

POSA/DFI
Gold, Position B
Total Area Scanned: 2.83 cm^2

Size Distribution (μm) Diameter	Particles/ (cm^2)	Relative Population
0 - 2	180	:*****
2 - 4	352	:**********
4 - 6	255	:*******
6 - 8	170	:*****
8 - 10	117	:***
10 - 12	71	:**
12 - 14	41	:*
14 - 16	39	:*
16 - 18	19	:
18 - 20	20	:
20 - 22	10	:
22 - 24	12	:
24 - 26	5	:
26 - 28	4	:
28 - 30	4	:
30 - 32	2	:
32 - 34	1	:
34 - 36	4	:
36 - 38	6	:
38 - 40	0	:

POSA/FF
Gold, Position B
Total Area Scanned: 2.83 cm^2

Size Distribution (μm) Diameter	Particles/ (cm^2)	Relative Population
0 - 2	113	:****
2 - 4	284	:************
4 - 6	203	:********
6 - 8	111	:****
8 - 10	51	:**
10 - 12	34	:*
12 - 14	42	:*
14 - 16	15	:
16 - 18	18	:
18 - 20	9	:
20 - 22	9	:
22 - 24	4	:
24 - 26	7	:
26 - 28	3	:
28 - 30	7	:
30 - 32	3	:
32 - 34	2	:
34 - 36	3	:
36 - 38	0	:
38 - 40	0	:

TABLE 7. POSA – PARTICLE DISTRIBUTION MEASUREMENTS.

POSA/DFI
1810 Å Filter, Position C
Total Area Scanned: 0.036 cm^2

Size Distribution (μm) Diameter	Particles/ (cm^2)	Relative Population
0 1	516	:***
1 2	1109	:*********
2 3	1061	:*********
3 4	776	:******
4 5	521	:****
5 6	361	.**
6 7	267	:**
7 8	213	:*
8 9	128	:
9 10	69	:
10 11	49	.
11 12	41	.
12 - 13	20	.
13 14	†	.
14 15	9	.
15 16	16	
16 17	6	.
17 18	†	.
18 19	0	:
19 20	6	:
20 30	10	:
30 40	0	:
40 50	2	:
50 100	†	.
100 500	3	
500 1000	1	.

POSA/FF
1790 Å Filter, Position C
Total Area Scanned: 1.35 cm^2

Size Distribution (μm) Diameter	Particles/ (cm^2)	Relative Population
0 - 10	137072	:*********
10 20	774	:
20 30	102	.
30 40	36	:
40 50	13	:
50 60	17	:
60 70	0	:
70 80	3	:
80 90	0	:
90 100	0	:
100 200	3	:
200 300	5	:
300 400	3	:
400 500	5	:
500 1000	0	:
		:
		:
		:
		:
		:
		:
		:
		:
		:
		.

†Invalid readings resulting from instrument error

TABLE 8. POSA - PARTICLE DISTRIBUTION MEASUREMENTS

POSA/DFI
Calcium Fluoride, Position D
Total Area Scanned: 2.83 cm^2

Size Distribution (μm) Diameter	Particles/ (cm^2)	Relative Population
0 - 2	195	:***
2 - 4	445	:*******
4 - 6	333	:*****
6 - 8	266	:****
8 - 10	322	:*****
10 - 12	229	:***
12 - 14	125	:**
14 - 16	119	:**
16 - 18	60	:*
18 - 20	78	:*
20 - 22	32	:
22 - 24	33	:
24 - 26	16	:
26 - 28	24	:
28 - 30	12	:
30 - 32	16	:
32 - 34	7	:
34 - 36	8	:
36 - 38	4	:
38 - 40	0	:
40 - 100	44	:
100 - 500	8	:

POSA/FF
Fused Silica, Position D
Total Area Scanned: 2.83 cm^2

Size Distribution (μm) Diameter	Particles/ (cm^2)	Relative Population
0 - 2	183	:******
2 - 4	311	:***********
4 - 6	160	:*****
6 - 8	175	:******
8 - 10	77	:**
10 - 12	45	:*
12 - 14	60	:**
14 - 16	41	:*
16 - 18	10	:
18 - 20	25	:
20 - 22	15	:
22 - 24	7	:
24 - 26	10	:
26 - 28	2	:
28 - 30	1	:
30 - 32	5	:
32 - 34	6	:
34 - 36	3	:
36 - 38	0	:
38 - 40	1	:
40 - 100	15	:
100 - 500	4	:

TABLE 9. POSA - PARTICLE DISTRIBUTION MEASUREMENTS.

POSA/DFI
Calcium Fluoride, Position E
Total Area Scanned: 2.90 cm^2

Size Distribution (μm) Diameter	Particles/ (cm^2)	Relative Population
0 - 2	68	:*
2 - 4	385	:********
4 - 6	259	:*****
6 - 8	326	:*******
8 - 10	194	:****
10 - 12	198	:****
12 - 14	141	:***
14 - 16	81	:*
16 - 18	43	:
18 - 20	33	:
20 - 22	22	:
22 - 24	16	:
24 - 26	16	:
26 - 28	3	:
28 - 30	10	:
30 - 32	9	:
32 - 34	1	:
34 - 36	3	:
36 - 38	3	:
38 - 40	3	.
40 - 50	7	:
50 - 100	10	:
100 - 500	1	:
500 - 1000	0	:

POSA/FF
Calcium Fluoride, Position E
Total Area Scanned: 2.66 cm^2

Size Distribution (μm) Diameter	Particles/ (cm^2)	Relative Population
0 - 2	12	:**
2 - 4	37	:*******
4 - 6	38	:*******
6 - 8	17	:***
8 - 10	23	:****
10 - 12	13	:**
12 - 14	11	:**
14 - 16	8	:*
16 - 18	5	:
18 - 20	8	:*
20 - 22	4	:
22 - 24	3	:
24 - 26	6	:*
26 - 28	2	:
28 - 30	1	:
30 - 32	2	:
32 - 34	3	:
34 - 36	2	:
36 - 38	1	:
38 - 40	1	:
40 - 50	0	:
50 - 100	12	:**
100 - 500	0	:
500 - 1000	0	:

detected on the gold or MgF_2/Al samples [3]. Similar measurements indicated similar results on POSA control samples; since 10^{-10} Coulombs is about the limit of measurement for this particular electrometer, and the results indicate no unique charging of the uv filters, the greater particle counts on the filters appear to have no relation to unique surface charging. No explanation is available for the anomalous low particle count on the CaF_2 sample of POSA/FF either; repeated measurements confirmed the results given.

RESULTS - ELECTRET ANALYSIS

The electrets are made of Teflon-Polytetrafluorethylene, $(C_2F_4)n$. Electrets are dielectrics with a permanent surface charge (approximately 10^{-8} Coulombs/cm^2 density) that gives them properties analougous to magnets by retaining electrically active particles and ions on their surface [4]. Measurements are made in the energy range from 0.707 to 30 keV ± 0.170 keV (i.e., fluorine to silver) using an X-ray microprobe to analyze the effluents collected on the Teflon electrets. Thus, an elemental analysis and an estimate of the abundance of the elements are obtained. The area scanned measured approximately 0.1 cm^2, selected arbitrarily by the microprobe operator for a representative area of particle density. The results show the elemental abundance of an aggregate of particles on the electret surface.

Three electrets were included in the POSA/DFI for STS-1. One was placed under Sample E, the calcium fluoride "window." For this electret, the surface normal was oriented 180 degrees (-Z) from the front surface normal of the CaF_2 sample for a measure of the directionality of effluent flow. The other two electrets were placed in sample slot "F" of the POSA holder (one facing "up", +Z, the other facing "down", -Z) for directionality analysis. In all cases, the positively polarized surface was the surface exposed.

Two electrets in the POSA/DFI, position E (-Z) and electret No. 10, position F, (-Z), showed no evidence of contamination present. Electret No. 11, also at position F but facing "+Z", showed a measurement of Si and Al after X-ray microprobe analysis. On the ferry flight of Columbia from Edwards AFB, California, to Kennedy Space Center, Florida, no significant amount of Si was collected on the POSA/FF electrets, but an increase of Al was measured on electrets 13 and 14 after the energy-dispersive analysis of the electrets. In Table 10 the relative abundance of the elements was obtained by dividing the observed value by the preflight measurements

The quantity and size distribution of particles on the orbital and ferry flight electrets are presented in Figures 29 through 32. As shown in the figures, the results indicated a size distribution weighted toward particles less than 20 μm in both the orbital and ferry mission. A comparison of the plots shows a greater number of particles obtained during the orbital mission than the ferry flight. These particle sizes were measured by a Bausch and Lomb Automatic System, a high-resolution particle sizing system.[2] At 10x magnification, the area scanned was 1.27 cm^2. Morphology studies with a scanning electron microscope (SEM) indicated irregularly shaped particles, generally less than 20 μm diameter.

2. The same system (ES74, MSFC) used for particle counting on the POSA optical **samples.**

TABLE 10. COMPARISON OF ELECTRET RESULTS DURING STS-1 ORBITAL FLIGHT AND FERRY FLIGHT.

Electret No.	Description	Electret	Relative Elemental Abundance (Total Counts Measured per Element)	Postflight Counts/ Preflight Counts
9	Cargo Bay, STS-1 DFI Pallet, Position (Down) (-Z)	Al	0	0
		Si	100	1.10
		Cl	35	1.06
		S	200	*
		Ca	3520	*
		Ag	100	*
10	Cargo Bay, STS-1 DFI Pallet, Position F (Down) (-Z)	Al	0	0
		Na	65	*
		Si	30	1.02
		Cl	0	0
		Au	30	*
		Ag	200	*
		K	65	**
		Cr	Trace	*
11	Cargo Bay, STS-1 DFI Pallet, Position F (Up) (+Z)	Al	11100	2.0
		Si	990	2.3
		Cl	0	0
		S	210	*
		Ag	280	*
13	Ferry Flight return of Columbia from Edwards AFB to KSC (Down) (-Z)	Al	8300	2.4
		Si	0	0
		Cl	0	0
		Ca	450	*
		Mg	30	*
14	Ferry Flight return of Columbia from Edwards AFB to KSC (Up)(+Z)	Al	3830	1.7
		Si	0	0
		NA	60	*
		Cl	0	0
		Ag	810	*
		Fe	Trace	*

* No counts measured preflight
** Trace measured in preflight

ELECTRET # 9 (DOWN, –Z)

DISTRIBUTION

0 –	10 (μ m)	1901	:***************
10 –	20	1760	:**************
20 –	30	645	:*****
30 –	40	235	:*
40 –	50	73	:
50 –	60	51	:
60 –	70	28	:
70 –	80	25	:
80 –	90	9	:
90 –	100	8	:
100 –	500	29	:
500 –	1000	1	:

ELECTRET # 10 (DOWN, –Z)

DISTRIBUTION

0 –	10 (μ m)	1562	:**************
10 –	20	1686	:***************
20 –	30	649	:*****
30 –	40	247	:**
40 –	50	93	:
50 –	60	44	:
60 –	70	22	:
70 –	80	13	:
80 –	90	2	:
90 –	100	5	:
100 –	500	39	:
500 –	1000	4	:

ELECTRET # 11 (UP, +Z)

DISTRIBUTION

0 –	10 (μ m)	947	:**************
10 –	20	949	:***************
20 –	30	424	:******
30 –	40	104	:*
40 –	50	43	:
50 –	60	10	:
60 –	70	12	:
70 –	80	7	:
80 –	90	3	:
90 –	100	1	:
100 –	500	6	:
500 –	1000	0	:

Figure 29. Particle size distributions on electrets on POSA/DFI.

ELECTRET # 13 (DOWN, –Z)

DISTRIBUTION

0 –	10 (μ m)	235	:* * * * * * * * * * * *
10 –	20	250	:* * * * * * * * * * * * *
20 –	30	111	:* * * * * *
30 –	40	58	:* * *
40 –	50	23	:*
50 –	60	15	:
60 –	70	6	:
70 –	80	7	:
80 –	90	3	:
90 –	100	6	:
100 –	500	11	:
500 –	1000	1	:

ELECTRET # 14 (UP, +Z)

DISTRIBUTION

0 –	10 (μ m)	405	:* * * * * * * * * * * * * *
10 –	20	455	:* * * * * * * * * * * * * * *
20 –	30	140	:* * * *
30 –	40	46	:*
40 –	50	37	:*
50 –	60	18	:
60 –	70	9	:
70 –	80	9	:
80 –	90	5	:
90 –	100	7	:
100 –	500	8	:

Figure 30. Particle size distributions on electrets on POSA/FF.

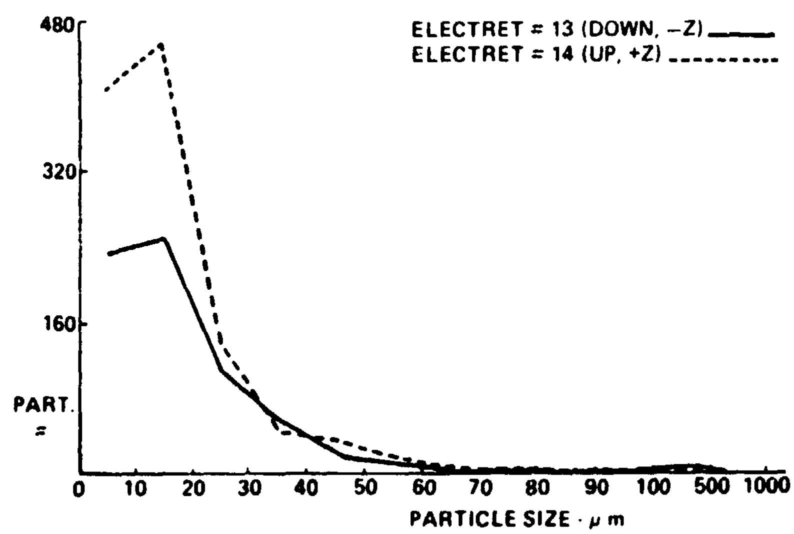


Figure 31. Particle distributions on electrets of POSA/FF.

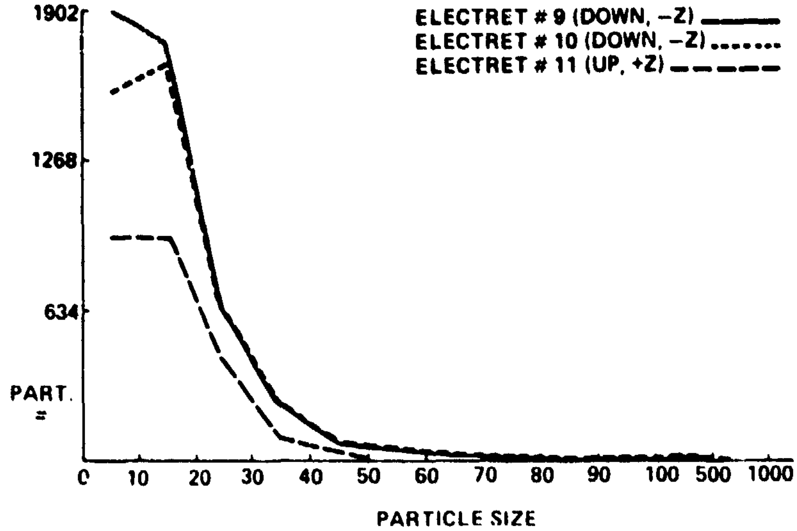


Figure 32. Particle distributions on electrets of POSA/DFI.

RESULTS - ELEMENTAL ANALYSIS OF OPTICAL SAMPLES

Scanning electron microscope investigations of the particles on the POSA samples revealed measurable levels of silicon and aluminum; other constituent elements were detected at levels below statistical significance. These results are inconclusive evidence of the chemical nature of the particles because the SEM probably detected base mirror constituents as well.

The smudged MgF_2/Al sample of POSA/DFI was subjected to Auger analysis. On the non-smudged area of the sample, silicon was detected in quantities sufficient to suggest the existence of a very thin silicone contaminant layer. Within the areas of the droplet and the smudge, no trace of silicon was detected. Instead, signficant levels of potassium, chlorine, sodium, and nitrogen, with trace quantities of sulphur were detected. The smudged areas contained the same chemical constituents as the droplet, though in measureably less quantity.

These types of Auger investigations on contaminated samples generally indicate a residue of chlorine and sulfur from greases, based on past experience. Potassium is not commonly found; for this case, it may be helpful to recall that potassium chlorine is usually found in human sweat. Nitrogen in the smudge and droplet is of unknown origin; it is sometimes detected as a trace contaminant from heated metals

The smudged POSA/DFI sample was subsequently subjected to a scanning electron microprobe analysis. Table 11 summarizes the results, showing the relative abundance of elements detected in both the smudge and the droplet. While the smudged area of the sample (~ 5000 μm diameter) is much larger than the droplet (μm diameter), the only elements detected in the smudge were magnesium, silicon, and aluminum. These peaks undoubtedly arose from the mirror itself, as independent investigations on control mirrors attest. The relative abundance of chemical constituents in the droplets with reference to the smudge, in the microprobe analysis, is due to the greater density of contaminant visibly apparent in the droplet.

TABLE 11. SCANNING ELECTRC' MICROPROBE ANALYSIS OF POSA/DFI MgF_2/Al MI. · ᴖR CONTAMINANTS

ELEMENT	PROPORTIONAL COUNTS
Chlorine	450
Magnesium	160
Silicon	5000
Aluminum	3000
Sodium	30
Phosphorous (or Zinc)	64
Sulphur	90
Potassium	650
Calcium	120

Independent investigations directed by Johnson Space Center (JSC) [3] of contamination in the Shuttle cargo bay provide some results correlative with the POSA material studies. These JSC results were obtained by analyzing the residue of a number of collecting "wipes" from the Shuttle fore and aft radiators, indicating non-particulate surface contaminant layers varying from 10^{-6} to 10^{-7} grams/cm^2. The equivalent thickness of the contaminant layers leading to such densities can be estimated as about one monolayer (20-30 Ångstroms), a result not incompatible with the optical and material properties results for POSA.

The volatility of the smudged contaminant is very low; repeated exposure to vacuum levels of 10^{-8} torr to 10^{-9} torr, from the vacuum ultraviolet and the material properties tests led to no discernible change in the quantity or appearance of the smudge or the droplet.

In summary, with respect to the smudge and the droplet:

- the composition is certainly not a silicone
- it has a very low volatility
- there was probably some human-associated interaction leading to the smudge
- it is likely a grease, with other contaminants present.

GENERAL CONCLUSIONS

At wavelengths greater than 3000 Å, there is no significant optical change on samples of either POSA unit, except for the smudged mirror.

The most probable cause of most of the observed uv optical degradation is particulate deposition since it is measured on both POSA units and the evolution of the volatile species leading to molecular film contamination would not be expected in the ferry flight environment. Although there are indications of spectral effects, usually associated with the molecular contaminant films, in the reflectance data for the mirrors and the ultraviolet filters, the associated measurement uncertainty is large and the magnitude of reflectance change is relatively low.

A significant degradation at wavelengths lower than 1700 Å was measured on the backside of DFI samples with a large view factor to the painted DFI structure.

There was evidence of a very thin silicone contaminant layer on the POSA/DFI samples from Auger analysis.

The smudge on the one DFI sample was not a silicone; it is probably a hydrocarbon grease.

The particulate levels were very high in the range of diameters < 5 μm for mirror samples of both POSA units and less on the transparent samples of both units, indicating significant variations in adherence.

It is emphasized that these results are for unprotected samples subjected to all phases of the flight, including the ferry flight. The STS-1 was subjected for many months to a relatively uncontrolled environment during manufacturing efforts. These results permit a first estimation of the anticipated degradation for unprotected (exposed) optics in the Shuttle cargo bay; it is expected that future Shuttle missions will be conducted with less environmental exposure in the prelaunch phases. These STS-1 results are, of course, based on data obtained from only a portion of one of the ten IECM instruments to be flown on several Shuttle flights beginning with STS-2. These limited results, however, do not indicate Shuttle contamination levels in excess of those which were anticipated. Much more definitive data will be obtained from the planned flights of the full IECM.

APPENDIX A

The basic philosophy of sample selection was determined by the relative contamination sensitivity and the relevance of concern for similar materials as components of future STS payloads:

A. MgF_2/Al: An optically flat ($\lambda/10$) fuxed silica substrate is coated with 100 Å thickness of aluminum which is, in turn, overcoated with a protective and reflective-enhancing 250 Å thick layer of magnesium fluoride. The substrate thickness is 32 mm (0.125 in.). This particular composition of thin film mirror provides the highest reflectance in the vacuum ultraviolet spectral range through, or down to, 1216 Å wavelength (Lyman α). Telescope mirrors and diffraction gratings are frequently of the same composition.

B. Au: The gold mirror consists of a 400 Å thickness layer of 0.9995 pure gold on a fused silica substrate. The substrates of all mirrors selected for use in the POSA are identical. Both gold and MgF_2/Al mirrors are standard components of space optical instrumentation. Gold is particularly useful as a coating for uv optical elements for its reasonable magnitude of reflectance and its well-known insensitivity to oxidation or tarnishing.

C. Filters: The vacuum ultraviolet filters are composed of a multilayer thin film composition deposited on magnesium fluoride substrates. The filters transmit a 225 Å bandwidth of light centered at the designated peak wavelength. Interference filters are common components of vacuum ultraviolet instruments flown in space. The transmission is highly sensitive to contamination. The filters are opaque to all wavelengths of light in the range of 0.12 to 2.5 μ except, of course, for the "narrow" bandwidth, as designated.

D. CaF_2: The calcium fluoride "window" is dimensionally identical to the mirror substrates; both sides are optically polished. Transmission extends through the ultraviolet. Because of hardness, resistance to water, uv-induced damage, and favorable transmission properties in the vacuum ultraviolet, calcium fluoride instrumentation (particularly as windows for environmentally sensitive detectors).

E. SiO_2: The fused silica window, optically polished on both sides ($\lambda/4$), measures 2.54 cm diameter, 2.5 mm thick. With the onset of transmission above 160 nanometers, this material is a common "window" for detectors having medium spectral vacuum ultraviolet sensitivity. It is also a common substrate for optical mirrors.

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APPROVAL

PASSIVE OPTICAL SAMPLE ASSEMBLY (POSA): FINAL REPORT

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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